MCNPX 2.7.X – New Features Being Developed

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Outline

- Overview
- Physics Enhancements
- Source Enhancements
- Tally Enhancements
- Other Enhancements
Overview – MCNPX is a 3-D, all-particle, all-energy Monte Carlo transport code

- **Monte Carlo radiation transport code**
  - Extends MCNP4C to virtually all particles and energies
  - 34 different particle types + 2205 heavy ions
    - Neutrons, photons, electrons, protons, pions, muons, light-ions, etc.
  - Continuous energy (~0 -1 TeV/n)
  - Data libraries below ~150 MeV (n,p,e,h) & models otherwise

- **General 3-D geometry**
  - 1st & 2nd degree surfaces, tori, 10 macrobodies, lattices

- **General sources and tallies**
  - Interdependent source variables, 7 tally types, many modifiers

- **Supported on virtually all computer platforms**
  - Unix, Linux, Windows, OS X (parallel with MPI)
Overview – The previous century of development
Overview – The current century of development

MCNPX Versions

LAHET
CEM
INCL
Cinder90
LAQGSM

MCNP4C
MCNP5

1995
2000
2005
2010

4A, 4B

2.1.5
2.3.0
2.4.0
2.5.0
2.6.0
2.7.0

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Overview – Why so many versions of MCNPX?

Alpha Versions

Beta Versions

Public Versions

1. Why so many versions of MCNPX?

2. Versions

2.7.A1 2.7.A2 2.7.A3 2.7.A4

2.7.A


2.7.B

2.7.C1 2.7.C2 2.7.C3 2.7.C4

2.7.C

2.7.D1 2.7.D2 2.7.D3 2.7.D4

2.7.D

2.7.0

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Overview – Resources for MCNPX users

- **~3000 users world wide**
  - Provide 6-8 workshops per year (4-6 US, 2 international)
  - 1-2 workshops per year have a HS or TR emphasis
  - Access to RSICC/NEA released versions only
    - http://www-rsicc.ornl.gov/ (C00740) 2.6.0
    - http://www.nea.fr/html/dbprog/ (CCC-0740) 2.6.0
  - Limited access to MCNPX web site
    - http://mcnpx.lanl.gov (some documentation)

- **~2000 registered Beta Users**
  - Full access to MCNPX web site
  - Access to intermediate Beta versions
  - Increased user support
Version 2.7.0 (2.7.A, 2.7.B, 2.7.C, 2.7.D)

Physics Enhancements
- CEM upgrade to 03.02
- Adjustable stopping-power grid
- LLNL photofission multiplicities
- Delayed gamma exact sampling
- LLNL neutron fission multiplicities
- Muonic x-ray enhancements
- Delayed neutron spectra
- NRF data in ACE libraries
- Correlated gamma production
- Improved photofission yields

Tally Enhancements
- Tally tagging
- LET tally option
- Quality factor tally option
- Cyclic tally binning
- ROC curve tally option
- Built-in detector response functions

Variance Reduction Enhancements
- Biased delayed-particle production

Source Enhancements
- Pulsed sources
- Beam source options
- Natural background sources

Other Enhancements
- MC PLOT graphics enhancements
- Activation options (ACT card)
- MC PLOT tally manipulations
- Dynamic universes
Physics Enhancements – CEM upgrade

1 Gev protons into N-14
1 1 -1.0 -1 imp:n=1
2 0 1 imp:n=0
1 so 1.0

mode n h d t s a
phys:n 1010
m1 7014 1
lca 7j -2 1 $ Turn on CEM
sdef par=h erg=1000
f1:n 1
e0 1 299log 1000
f11:h 1
f21:d 1
f31:t 1
f41:s 1
f51:a 1
nps 10000000
print

2.6.0 neutron proton
2.7.A deuterontritonhelionalpha

~4 times faster!
Physics Enhancements – Stopping powers

1 Gev protons into N-14
1 1 -1.0 -1 imp:n=1
2 0 1 imp:n=0
1 so 200.0

mode n h d t s a
phys:n 1010
phys:h 1010 9j .99 $ J for default
ml 7014 1
lca 8j 1
sdef par=h erg=1000
f4:h 1
e4 1 2000log 1000
nps 10000000
print

EFAC=0.92

EFAC=0.99
Physics Enhancements – LLNL multiplicities

12 MeV x-rays into U-235
1 1 -19.0 -1 imp:n=1
2 0 1 imp:n=0

1 so 1.0

mode n p
ml 92235 1 pnlib=.70u
PHYS:P j 1 j 1 2j 0 $ 0=ACE,1=LLNL
sdef par=p erg=12
LCA 7j -2
print
nps 1000000
fl:n 1
e1 1e-6 199log 12
fll:p 1
e11 1e-3 199log 12
ftll tag 3
full -1 0.00004 92000.00003
92235.00005 92000.00005
92235.00018 1e10

ACE Non-fission
LLNL Fission
LLNL Non-fission
Physics Enhancements – Exact DG sampling

Thermal neutrons into U-235

1  1  -8.9  -1  imp:n=1
2  0  1  imp:n=0

1  so  1.0

ml  92235.70c  1.0
mode  n  p
phys:p  5j  -102 $ Analog line data
cut:n  j  j  0.0
lca  7j  -2
sdef  par=n  erg=2.54e-8
f1:p  1
e1  0.0  399i  10
sdl  1
tl  1e4  1e30
tf1  7j  2
nps  25000
print
prdmp  2j  1
Physics Enhancements – Muonic x-rays

150 MeV muons into Pb/U

1  1  -19.0  -1  imp:p=1
2  2  -11.4  1  -2  imp:p=1
3  0  2  imp:p=0

1  so  2.0
2  so  7.0

mode | p
phys: | 400
m1   92235 1
m2   82208 1
sdef par=| erg=150 pos=-6.99 0 0
vec=1 0 0 dir=1
f1:p 2
e1  1e-3 199i 10.0
nps 10000000
print
Physics Enhancements – DN spectra

1 eV neutrons into U-235
1 1 -19.0 -1 imp:n=1
2 0 1 imp:n=0

1 so 4.0

ml 92235 1
phys:n 3j 105
lca 7j -2
sdef par=n erg=1e-6
print
nps 100000000
f1:n 1
e1 1e-7 199log 10
t1 0.001e8 1e30
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Tally Enhancements

- Tally tagging
- LET tally option
- Quality factor tally option
- Cyclic tally binning
- ROC curve tally option
- Built-in detector response functions

Source Enhancements

- Pulsed sources
- Beam source options
- Natural background sources

Variance Reduction Enhancements

- Biased delayed-particle production

Other Enhancements

- MCPLLOT graphics enhancements
- Activation options (ACT card)
- MCPLLOT tally manipulations
- Dynamic universes
Source Enhancements – Pulsed sources

SDEF TME=D41

# si41 sp41
S   D
51<52  .1
(31<32<33) .8
61  .1
si51 H 0 1 2
sp51  0 1 0
si52 A -26 -16
sp52  0 1
si31  0 1 2
sp31  0 1 0
si32  0 16
sp32 -41 8 8
si33 -16 32
sp33  0 1
si61 A 32 40
sp61  1 0
Source Enhancements – Beam sources

SDEF  PAR=|  ERG=100  POS=0 0 0  AXS=0 0 1  VEC=1 0 0
BEM=9.776e-3 9.776e-3 100  BAP=1.0 1.0 0

Disk source positioned at POS, with a normal given by AXS and an orthogonal axis by VEC
Source Enhancements – Beam sources

Beam transport in vacuum

Beam transport in air

z axis

L=100 cm

2 cm

z=0

2 cm
Source Enhancements – Background sources

Background source for NYC
1 0 -1 5 imp:n=1
5 0 -5 imp:n=1
99 0 1 imp:n=0

1 rpp -100 100 -100 100 0 200
5 s 0 0 0 5

mode n p
phys:n 5e5
phys:p 1e5
sdef PAR=bg LOC=40.78 73.97 0 $ NYC
  X=d1 Y=d2 Z=d3 WGT=2.333e4
si1 -100 100
sp1 0 1
si2 -100 100
sp2 0 1
si3 0 200
sp3 0 1
f4:n 5
e4 1e-8 49log 1e6
f14:p 5
e14 0 1999i 10
nps . 50000000
print

New York, NY
(.009 n/cm²/s)

Long Beach, CA
(.007 n/cm²/s)
Version 2.7.0 (2.7.A, 2.7.B, 2.7.C, 2.7.D)

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### Tally Enhancements – Tally tagging

**Neutron activation of water + HEU**

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
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</thead>
<tbody>
<tr>
<td>1 2</td>
<td>-10.0</td>
<td>-1</td>
</tr>
<tr>
<td>2 1</td>
<td>-1.0</td>
<td>1 -2</td>
</tr>
<tr>
<td>3 0</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

**Tally tagging**

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<tr>
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<th>Column 2</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>f31:n 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ft31: tag 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>fu31: -1.0</td>
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**NPS Overlap**

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<tbody>
<tr>
<td>1 sph 0 0 0</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 sph 0 0 0</td>
<td>40</td>
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**Energy Segregation**

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**Mode and Physical Settings**

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**SDEF and Energy Settings**

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**M1 and M2**

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**NPS**

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**Prompt and Delayed Time Bins**

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<tr>
<td>t31</td>
<td>100</td>
<td>1e15</td>
</tr>
<tr>
<td>e31</td>
<td>0</td>
<td>499i 20</td>
</tr>
</tbody>
</table>
Tally Tagging

40-cm-radius tank of H₂O

Tally neutron spectrum

14 MeV Neutrons

1kg HEU

Total over all reactions

Prompt

Delayed

Source + elastic scatter (-1 tag)
Tally Tagging

\[ ^{16}\text{O} \] [n,n' 2\text{nd}] [n,n' 1\text{st}] [n,n' 3\text{rd}] [n,n' 5\text{th}] [n,n' 4\text{tht}] [n,2n] [n,n' \alpha] [n,n' \alpha]^{14}\text{C} [n,n' \alpha]^{18}\text{O} [n,n' \alpha]^{17}\text{N} \]

\[ ^{17}\text{O} \] [n,n' 2\text{nd}] [n,n' 3\text{rd}] [n,n' 4\text{tht}] [n,n' 5\text{th}] [n,2n]^{17}\text{O} [n,n' \alpha]^{16}\text{O} [n,n' \alpha]^{17}\text{N} \]

\[ ^{235}\text{U} [n,f] \] [n,n' 1\text{st}] [n,n' 2\text{nd}] [n,n' 3\text{rd}] [n,n' 4\text{tht}] [n,n' 5\text{th}] \]

\[ ^{17}\text{O} \] [n,n' 1\text{st}] [n,n' 2\text{nd}] [n,n' 3\text{rd}] [n,n' 4\text{tht}] [n,n' 5\text{th}] \]

\[ ^{238}\text{U} [n,f] \] [n,n' 1\text{st}] [n,n' 2\text{nd}] [n,n' 3\text{rd}] [n,n' 4\text{tht}] [n,n' 5\text{th}] \]

Delayed Prompt Delayed Prompt
Tally Enhancements – LET option

1 MeV photons into Si
1 1 -2.0 -1 imp:p,e=1
2 0 1 imp:p,e=0

1 so 10.0

MODE p e
M1 14028 1
sdef par=p erg=1
f4:e 1
e4 .01 199log 1000 $ MeV/cm
ft4 LET
nps 1000000
print
Tally Enhancements – Quality factors

14 MeV n into water
1 1 -1.0 -1 imp:n=1
2 0 1 imp:n=0

1 so 10.0

m1 1001 2 8016 1
mode n h d t s a / z #
lca 8j 1 1
sdef
e0 0 99i 15
c
fc16 Dose equiv
f16:h 1
df16 ic=99 iu=1 fac=-3
c
fc116 Dose
f116:h 1
Tally Enhancements – Cyclic binning

Pulsed 15-MeV gammas into U-235
1 1 -19.0 -1 imp:p=1
2 0 1 imp:p=0

1 so 10

m1 92235 1
mode p
phys:p 3j 1 j -101
lca 7j -2
sdef par=p erg=15 tme=d1<d2
si1 0 0.000001e8 .001e8
sp1 0 1 0
si2 0 1e8
sp2 0 1
f1:p 1
T1 CBEG=0.0 CFRQ=1000e-8
  COFI=0.000005e8 CONI=0.0005e8 CSUB=5
ft1 tag 1
ful 92235.99999 92000.0
nps 100000000
print

1 μs pulse every 1 ms out to 1s

Tally on emitted γs

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Tally Enhancements – Cyclic binning

Cyclic time feature accumulates contributions across all 1000 repeated bins.

Full time-dependent behavior of 1000 pulses with dead/alive time bins repeated every 1 ms. Note decay after beam is turned off.
Version 2.7.0 (2.7.A, 2.7.B, 2.7.C, 2.7.D)

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- MC PLOT graphics enhancements
- Activation options (ACT card)
- Contout Legend in Geometry Plotter
Other Enhancements – MC PLOT graphics

```
mcploit>
Help
Type "help all" for a verbose list of all help commands
"help <command>" to list a specific help command,
"help overview" for an overview of MC PLOT,
or "help execute" for MC PLOT input & execution-line
mcploit>
```
Other Enhancements – Activation

14 MeV neutron activation of water
1 1 -1.0 -1 imp:n=1
3 0 1 imp:n=0

1 sph 0 0 0 40

mode n p
cut:n 2j 0 0
phys:n 3j 105 $ Bias DN
phys:p 5j -102 $ Analog DG
ACT NONFISS=all
sdef erg=14 par=n pos=-39.999 0 0
m1 1001 200.0
  8016 99.762
  8017 0.038
  8018 0.200
nlib=.70c
f11:n 1
t0 1000 1e15 $ Prompt & delayed
e0 0 499i 20
f21:p 1
nps 1000000
print

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NATIONAL LABORATORY
EST. 1943
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UNCLASSIFIED
Other Enhancements – Contour Legend

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Summary

- 23 features added or planned for 2.7.0.
- Release data tentatively scheduled for Summer 2010.
- MCNP6 (merged MCNPX & MCNP5) could supersede 2.7.0.
- Slides available on MCNPX website mcnpx.lanl.gov/documents/LAUR-09-06788.pdf