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MCNPX Overview

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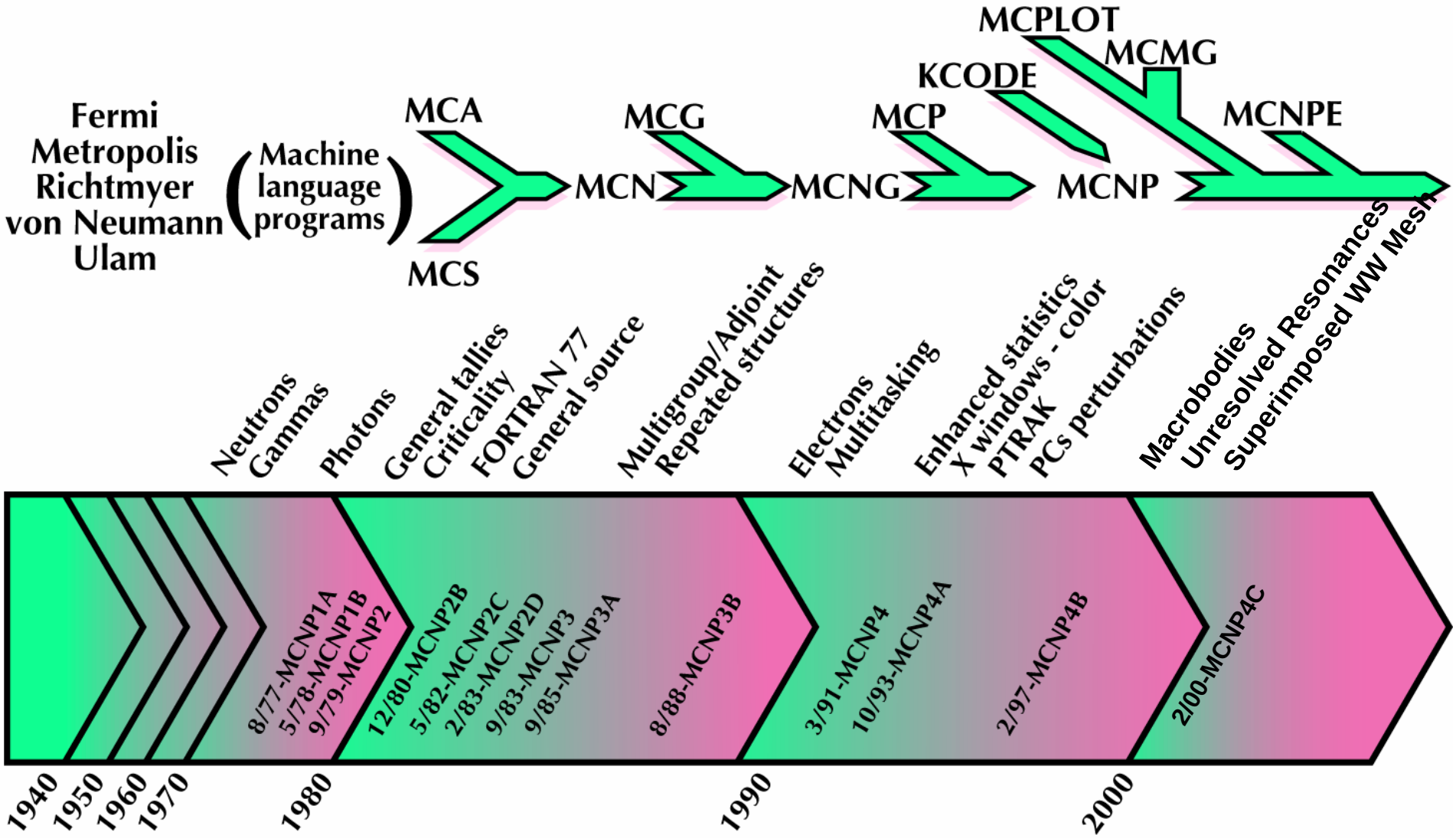
Outline

- **MCNPX Summary and Development History**
- **User Base, Web Site, Development Philosophy**
- **Physics and Capability Details**
- **Select 2.5.0 Features**
- **Future Development**

MCNPX Summary

- **Monte Carlo radiation transport code**
  - Extends MCNP 4C to virtually all particles and energies
  - 34 particle types (n,p,e,5 Leptons,11 Baryons,11 Mesons, 4 LI)
  - Continuous energy (roughly 0-100 GeV)
  - Data libraries below ~ 150 MeV (n,p,e,h) and 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 PVM or MPI)

HISTORY OF MCNP DEVELOPMENT



Development History

- **MCNP & LAHET Merger Project** **1995**
- **Version 2.1.5** **November 14, 1999**
  - HISTP/HTAPE3X, Mesh & radiography tallies, CEM
- **Version 2.3.0** **April 27, 2002**
  - Proton libraries
- **Version 2.4.0** **August 1, 2002**
  - Update to MCNP 4C, Fortran 90, Windows PC support
- **Version 2.5.0** **March 21, 2005**
  - Twenty-eight features

Development History

- **Version 2.6.A** **December 5, 2005**
  - Eigenfunction convergence, Burnup, Long file names
- **Version 2.6.B** **June 1, 2006**
  - CEM 03, Updated PHTLIB, Burnup predictor-corrector
- **Version 2.6.C** **~November, 2006**
  - Activation n+γ, Spherical WW, Photon tally tagging
- **Version 2.6.D** **~February, 2006**
  - Radioactive sources, PN improvements, LAQGSM
- **Version 2.6.0** **~Fall, 2007**

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User Base

- **~2500 users world wide**
  - Provide 6-8 workshops per year (4-6 US, ~2 international)
  - 150 workshop participants per year
  - Access to RSICC/NEA released versions only
    - http://rsicc.ornl.gov
  - Limited access to MCNPX web site
    - http://mcnpx.lanl.gov (some documentation)
- **~2000 registered Beta Testers**
  - Full access to MCNPX web site
  - Access to intermediate versions
  - Increased user support

Application	# Groups	Percent
Medical (BNCT, proton therapy, etc.)	63	16
Spacecraft, Cosmic Rays, SEE, propulsion	56	14
Detectors, experiments, Threat Reduction	55	14
Accelerator Shielding and Health Physics	43	11
Fuel cycles, beginning to end, including storage	40	10
ATW, ADS, Energy Amplifiers	38	9
Theoretical Physics	25	6
Neutron Production for Scattering	23	6
Isotope Production	14	3
Radiography	14	3
MCNPX/MCNP code development	12	3
Materials studies (IFMIF)	6	1
Radioactive Ion Beams	5	1
Irradiation Facilities	5	1
Neutrino Targets	4	1
Light Sources, electron machines	3	1

MCNPX

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Welcome to the home of the MCNPX code!

MCNPX is a general-purpose Monte Carlo radiation transport code for modeling the interaction of radiation with everything. MCNPX stands for Monte Carlo N-Particle eXtended. It extends the capabilities of MCNP4C3 to nearly all particle types, to nearly all energies, and to nearly all applications without additional computational time penalty. MCNPX is fully three-dimensional and time dependent. It utilizes the latest nuclear cross section libraries and uses physics models for particle types and energies where tabular data are not available. Applications range from outer space (the discovery of water on Mars) to deep underground (where radiation is used to search for oil.) MCNPX is used for nuclear medicine, nuclear safeguards, accelerator applications, nuclear criticality, and much more.

MCNPX is available (source code, executables, data) from the Radiation Safety

MCNPX

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MCNPX Source Code Page

This is the place to find copies of the code.

General Release

MCNPX version 2.5.0 is currently available from RSICC, The Radiation Safety Information Computational Center at Laboratory. It will soon be available from OECD/NEA, The European Community Organization for Economic Coope Nuclear Energy Agency.

For code access, contact RSICC or OECD/NEA for copies.

Beta Release

MCNPX is under active development and newer versions are available to beta testers under a beta test agreement. The beta testing program should contact the MCNPX team, mcnpx@lanl.gov, for information.

Beta testers can access the code by using Beta Release access.

Developer Release

For sponsors and MCNPX developers, intermediate developmental versions are available. Developers can access the access.

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MCNPX Document Page

Reports and Papers

Gregg W. McKinney et al., "MCNPX Overview", LA-UR-06-???? (278 KB), Proceedings of the 2006 HSSW, FNAL 2006.

Gregg W. McKinney et al., "MCNPX 2.5.0 - New Features Demonstrated", LA-UR-04-8695 (278 KB), Proceedings c Conference, Chattanooga, Tennessee, April 17-21, 2005.

John S. Hendricks, "MCNPX Model/Table Comparison," LA-14030 (March 2003) (3.3 MB), is a 50-page report dem mix-and-match capability and assessing the ability to use neutron physics models below 20-MeV.

The following papers describe the CEM03 physics model: LA-UR-06-1764 cover page (.05 MB), LA-UR-06-1764 (.8

The following papers describe the INCL4 physics model (IntraNuclear Cascade Liege - Cugnon) and ABLA physics r Schmidt(GSI)): NuclPhys620_475 (1.5 MB), NuclPhys625_729 (1.2 MB), NuclPhys628_458 (1.0 MB), NuclPhys62 PhysRevC33_2039 (3.1 MB), PhysRevC66_44615 (.5 MB).

The following describe the MCNP5 photon Doppler broadening capability which is now available in MCNPX: LA-U UR-04-0488.pdf . These are LANL memoranda by Avneet Sood, "Doppler Energy Broadening for Incoherent Scatter: 5:AS-02-16, July 31, 2002, 11 pages, .164 MB) and Part 2 (X-5:AS-02-17, July 31, 2002, 23 pages, .158 MB).

Installation Notes:

Development Philosophy

- **Quality**
  - Active Beta Testers (~2000)
  - Bug rewards ($4 for old bugs, $20 new bugs)
  - Extensive test suite (~300 problems, ~75% coverage)
- **Value**
  - Thorough documentation (manual, web site)
  - Users forum
  - Three levels of workshops (intro, intermediate, advanced)
- **Features**
  - Beta release ~3 months
  - Public release ~2 years
  - Average ~1 feature/month

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General	MCNPX	GEANT4	FLUKA	MARS	PHITS
Version	2.5.0	8.0 p1	2005	15	2.09
Lab. Affiliation	LANL	CERN IN2P3 INFN KEK SLAC TRIUMF ESA	CERN INFN	FNAL	JAEA RIST GSI Chalmers Univ.
Language	Fortran 90/C	C++	Fortran 77	Fortran 95/C	Fortran 77
Cost	Free	Free	Free	Free	Free
Release Format	Source & binary	Source & binary	Source & binary	Binary	Source & binary
User Manual	470 pages	280 pages	387 pages	150 pages	176 pages
Users	2500	~2000	~1000	220	220
Web Site	mcnpx.lanl.gov	cern.ch/geant4	www.fluka.org	www-ap.fnal. gov/MARS	Under const.
Workshops	~7/year	~4/year	~1/year	~2/year	~1/year
Input Format	Free	C++ main Fixed geometry	Fixed or free	Free	Free
Input Cards	~120	N/A	~85	~100	~100
Parallel Execution	Yes	Yes	Yes	Yes	Yes

Geometry	MCNPX	GEANT4	FLUKA	MARS	PHITS
Description	MCNP-based	STEP Solids (Boolean CSG)	MORSE-based	Solids MCNP-based User defined	MCNP-based MORSE-based
Extensions Twisted Nested Repeated Voxel	 No Yes (universes) Yes Lattice (rec, hex)	 Yes Yes (logical vol.) Yes Yes (rec, cyl)	 No No Yes Yes	 No Yes Yes Yes	 No Yes (universes) Yes Lattice (rec, hex)
Reflections	3 types	Yes	Yes	Yes	Neutron albedo
Viewer **Debugger**	Built-in: 2-D Interactive X-Windows External: Vised Moritz	Built-in: 3-D Interactive OpenGL OpenInventor RayTracer External: WIRED VRML DAWN	Built-in: None External: Custom (X11) Others?	Built-in: 2-D Interactive Tcl/Tl 3-D Interactive OpenGL External: Custom	Built-in: 2,3-D Command PS via Angel External: Angel PS
Setup GUI	Vised Moritz	GGE	No	Tcl/Tl	No
CAD	STEP via GUI	STEP	No	No	No
Fields (E/B)	2.6.0	Yes	Yes	Yes	Yes
Moving	2.6.0	Yes	Yes	No	Yes

Source	MCNPX	GEANT4	FLUKA	MARS	PHITS
Fixed					
General					
Explicit	Yes	Yes	Yes	Yes	Yes
Distribution	Yes	Yes	No	Yes	Yes
Dep. Dist.	Yes	GPS	No	Yes	Yes
External	SSW/SSR	Yes	No	Yes	Yes
User Sub.	Yes	Yes	Yes	Yes	Yes
Eigenvalue	Yes	No	No	No	No
Burnup	Yes (2.6.A)	No	No	No	No

Physics	MCNPX	GEANT4	FLUKA	MARS	PHITS
Particles	34	68	68	41	38
Charged particles	CSDA	CSDA	CSDA	CSDA	CSDA
Energy loss	Bethe-Bloch	Bethe-Bloch	Bethe-Bloch	Bethe-Bloch	Bethe-Bloch
Scatter	Rossi	Lewis	Moliere	Moliere*	Moliere
Straggling	Vavilov	Urban	Custom	Custom	Vavilov
XTR/Cherenkov	No	Yes	No/yes	No	No
Baryons					
Neutron					
Low	Cont. (ENDF)	Cont. (ENDF)	Multigroup(72)	Cont. (ENDF)	Cont. (ENDF)
High	Models	Models	Models	Models	Models
Proton					
Low	Cont. (ENDF)	Models	Models	Models	Models
High	Models	Models	Models	Models	Models
Other	Model List: Bertini ISABEL CEM INCL FLUKA89>3 GeV LAQGSM (2.6.D)	Model list: Hadron-nucleous GHEISHA* INUCL(Bertini) BIC CHIPS QGS/FTF>8 GeV	Model list: PEANUT(GINC) DPM+Glauber > 5 GeV	Model list: Custom CEM LAQGSM DPMJET	Model list: Bertini JAM>3 GeV
Leptons					
Electrons	ITS 3.0	EEDL, EADL	Custom	Custom	ITS 3.0
Muon	CSDA/decay	Models	Models	Models	CSDA/decay
Neutrino	Production	Production	Models	Models	Models
Other	Decay	Decay	Decay	Models	Models

Physics	MCNPX	GEANT4	FLUKA	MARS	PHITS
Mesons	Models	Models	Models	Models	Models
Photons Optical x-ray/γ Photonuclear	 No ITS 3.0 Libraries (IAEA) CEM	 Yes EPDL97, EADL CHIPS	 Yes Custom+EPDL97 PEANUT VMDM	 No Custom Custom CEM	 No ITS 3.0 No
Ions	ISABEL LAQGSM (2.6.D)	AAM EDM BLIC	RQMD-2.4 DPMJET-3	LAQGSM	JQMD JAMQMD > 3 GeV/u
Delayed	n,γ (2.6.C)	α,β,γ	β,γ	γ	n

Tallies	MCNPX	GEANT4	FLUKA	MARS	PHITS
Standard					
Flux					
Volume	Yes	Yes	Yes	Yes	Yes
Surface	Yes	Limited	Yes	Yes	Yes
Point/ring	Yes	No	No	Yes (neutrons)	No
Current	Yes	Limited	Yes	Yes	Yes
Charge	Yes	Yes	Yes	Yes	Yes
Kinetic energy	Yes	Yes	Yes	Yes	Yes
Particle density	Yes	Yes	No	No	No
Reaction rates	Yes	No	Star (inelastic)	Yes	Yes
Energy deposition	Yes	Yes	Yes	Yes	Yes
Rapidity	No	Yes	Yes	Yes.	No
DPA	HTAPE3X	??	Some	Yes	Yes
Momentum	No	Yes	Yes	Yes	No
Pulse-height	Yes	User input	Yes	No	Yes
Termination	Partial	??	Yes	Partial	Yes
Modifiers	9	2	2	2	2
Special					
Mesh	rec, cyl, sph	rec, cyl	rec, cyl	rec, cyl, sph	rec,cyl
Coincidence	Yes	No	Yes	Yes	Yes
Residuals	Yes	No	Yes	Yes	Yes
Activation	2.5.D	??	Yes	Yes	No
Event logs	Yes	Yes	Yes	Yes	Yes
Convergence Tests	10	Error	Error	Error	Error

Tallies	MCNPX	GEANT4	FLUKA	MARS	PHITS
Viewer	Built-in: 1-D, 2-D Custom X-Windows External: IDL Tecplot GNUplot PAW	Built-in: No External: JAS PI Open Scientist	Built-in: None External: Custom (X11) GNUplot PAW ROOT	Built-in: Custom External: PAW	Built-in: Angel External: Angel
Variance Reduction					
Population control					
Region biasing	Yes	Yes	Yes	Yes	Yes
Weight cutoff	Yes	Yes	Yes	Yes	Yes
Weight window mesh	Yes	Yes	Yes	Yes	Yes
Energy biasing	Yes	No	Yes	Yes	Yes
Modified sampling					
Source biasing	Yes	RDM	Yes	Yes	Yes
Implicit capture	Yes	Yes	Yes	Yes	Yes
Exp. transform	Yes	No	Yes	Yes	No
Production biasing	Yes	Yes	Yes	Yes	Yes
Angular bias	Via DXTRAN	??	Yes	Yes	Yes
DXTRAN	Yes	No	No	No	No
Viewer	2-D contour	No	No	No	No

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Select 2.5.0 Features

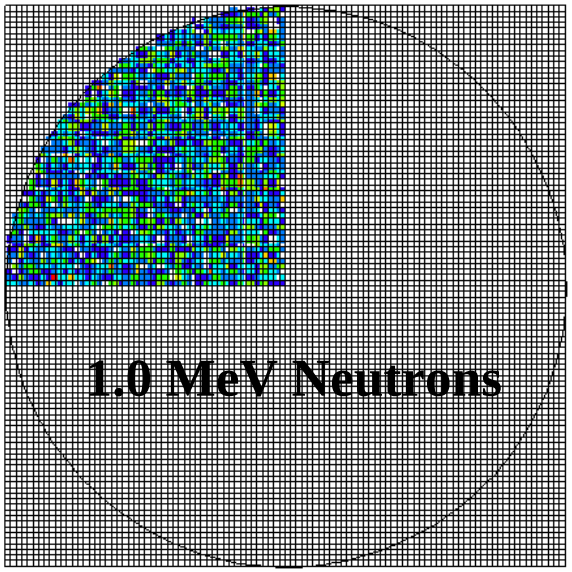
- **User-interface enhancements (15)**
  - 5 new source options
  - 4 new tally options
  - 3 new graphics options
  - 3 other miscellaneous improvements
- **Physics enhancements (9)**
  - 4 new model physics features
  - 2 new neutron physics features
  - 3 new photon physics features
- **Infrastructure enhancements (4)**

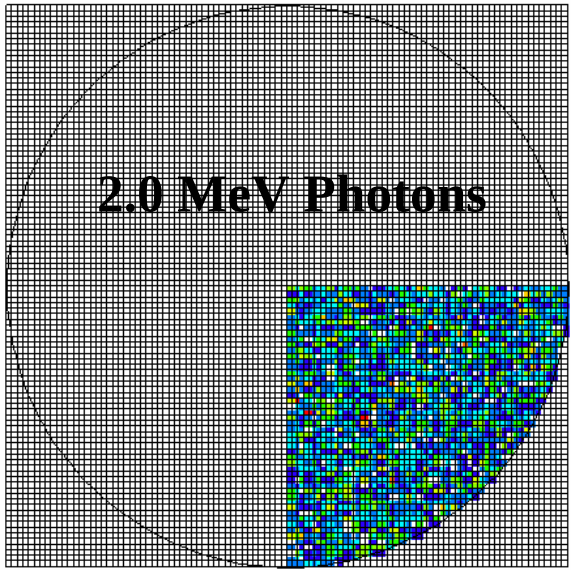
User-Interface Enhancements

- **Five new source options**
  - Positron sources
  - Spontaneous fission sources
  - Multiple source particles
  - Default VEC for cylindrical sources
  - Extension of the TR keyword

Multiple Source Particles / TR Extension

```
Distribution for PAR and TR Keywords
1  0    -1    imp:n=1
2  0     1    imp:n=0

1 SPH 0 0 0 100

mode n p
sdef  par=d1 erg=fpar=d2 tr=fpar=d3
      x=d4 y=d5 z=0 cell=1
si1   L n   p
sp1     1   1
ds2   L 1.0 2.0
ds3   L 1   2
si4   -50 50
sp4     0  1
si5   -50 50
sp5     0  1
tr1   -50  50 0
tr2    50 -50 0
nps  10000
tmesh
 rmesh2  n p
 cora2  -100 99i 100
 corb2  -100 99i 100
 corc2  -1 1
endmd
```



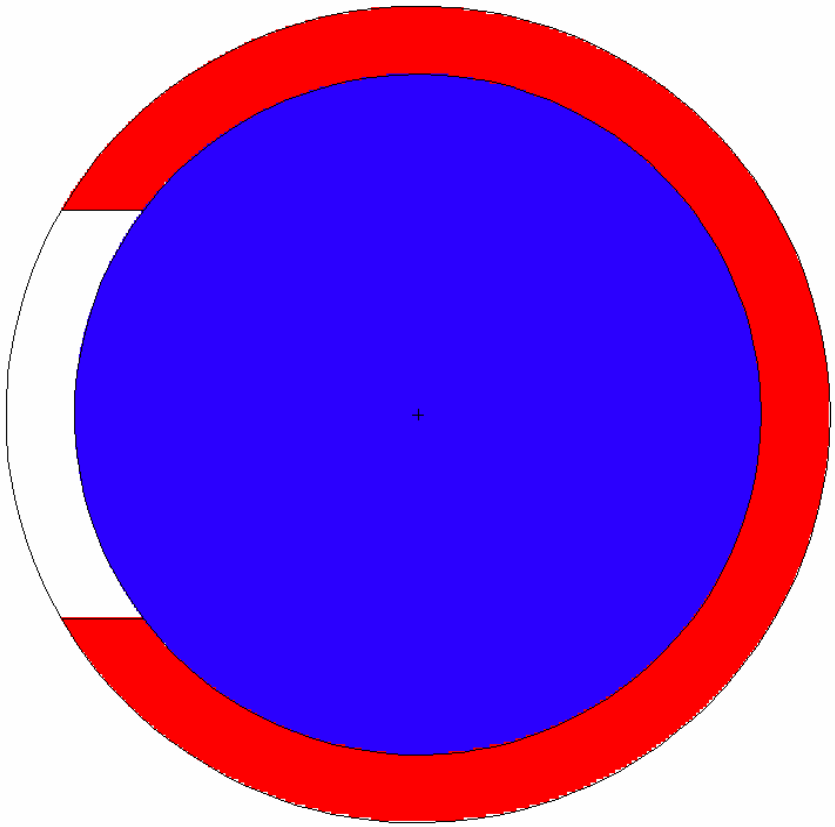


User-Interface Enhancements

- **Four new tally options**
  - Lattice tally speedup
  - Anticoincidence pulse-height tally
  - Coincidence capture pulse-height tally
  - Residual nuclei pulse-height tally

Anticoincidence Pulse-Height Tally

```
Anticoincidence PHT 1 MeV Photons => Plastic/BGO
1 1 -7.130 -1        imp:p=1
2 2 -1.032  1 -2  3 imp:p=1
3 0         1 -2 -3 imp:p=1
4 0         2        imp:p=0

1 SPH 0 0 0 5.0
2 SPH 0 0 0 6.0
3 RCC -7 0 0 4 0 0 3.0

mode p e
sdef sur=2 nrm=-1 par=p erg=1.0
nps  100000
m1   83000 -0.671 32000 -0.175 8000 -0.154
m2   6000 -0.9153 1000 -0.0847
f26:e  2                  $ Plastic energy dep
ft26   GEB 0 0.1098 0
sd26   1
f36:e  1                  $ BGO energy dep.
ft36   GEB 0 0.1098 0
sd36   1
f18:e  1                  $ Plastic/BGO PHT
e18    0. 1.0
fu18   0. 99i 1.0
ft18   phl 1 26 1 1 36 1
fq18   u e
```



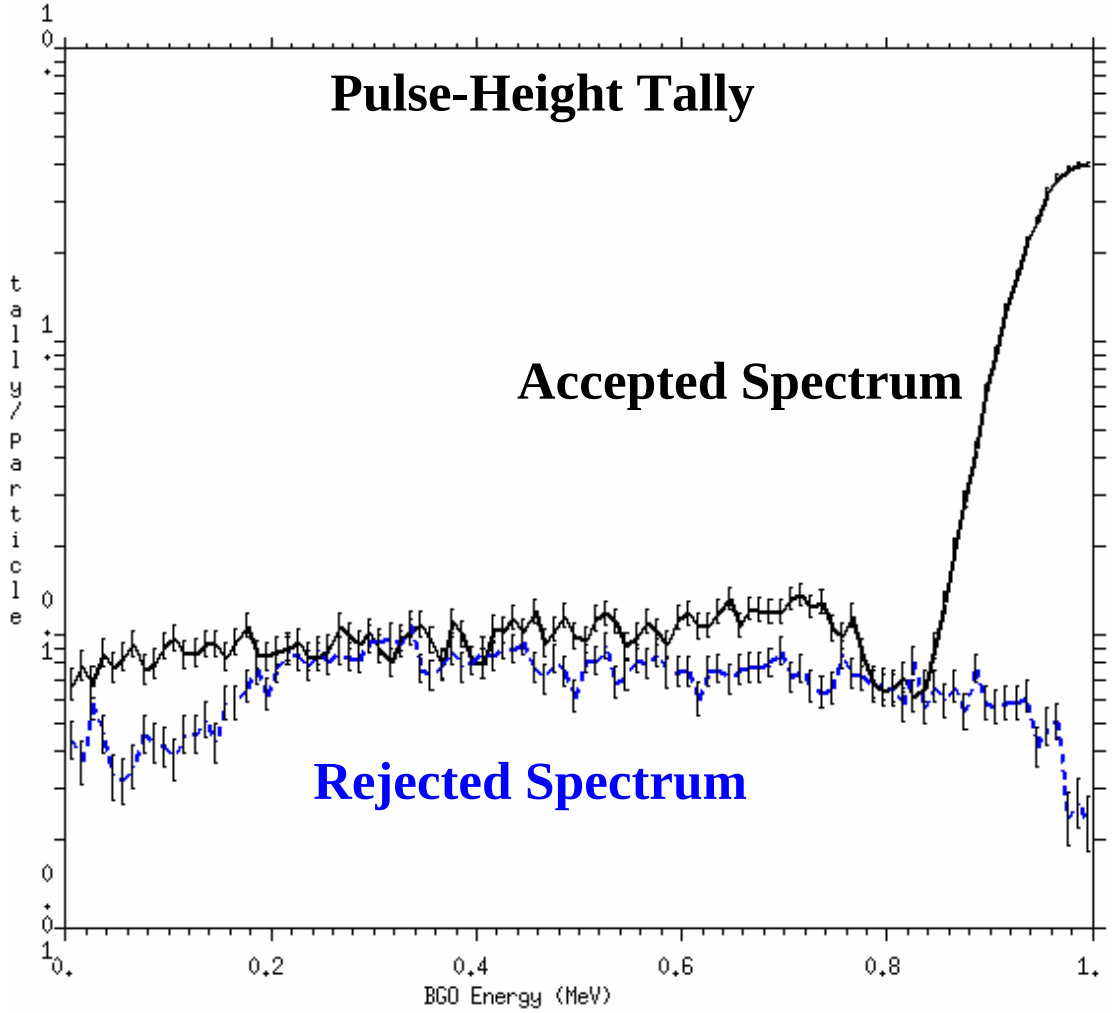
Anticoincidence Pulse-Height Tally

```
1tally  18        nps =   100000
+                                   ACS/BGO Pulse Height Response - all particles
          tally type 8    pulse height distribution.                  units   number
          particle(s): photon      electron
          this tally is modified by   ft  phl

 cell  1
       energy:       0.0000E+00          1.0000E+00             total
    user bin
    0.0000E+00   1.30000E-04 0.2773   8.84300E-02 0.0102   8.85600E-02 0.0101
    1.0000E-02   6.80000E-04 0.1212   4.40000E-04 0.1507   1.12000E-03 0.0944
    2.0000E-02   7.90000E-04 0.1125   3.70000E-04 0.1644   1.16000E-03 0.0928
    3.0000E-02   6.90000E-04 0.1203   5.90000E-04 0.1302   1.28000E-03 0.0883
    4.0000E-02   8.70000E-04 0.1072   4.60000E-04 0.1474   1.33000E-03 0.0867
    5.0000E-02   7.80000E-04 0.1132   3.30000E-04 0.1740   1.11000E-03 0.0949
    6.0000E-02   8.40000E-04 0.1091   3.20000E-04 0.1767   1.16000E-03 0.0928
    7.0000E-02   9.30000E-04 0.1036   3.60000E-04 0.1666   1.29000E-03 0.0880
    8.0000E-02   7.60000E-04 0.1147   4.60000E-04 0.1474   1.22000E-03 0.0905
    9.0000E-02   8.00000E-04 0.1118   4.30000E-04 0.1525   1.23000E-03 0.0901
    1.0000E-01   9.20000E-04 0.1042   4.20000E-04 0.1543   1.34000E-03 0.0863
    1.1000E-01   9.80000E-04 0.1010   3.80000E-04 0.1622   1.36000E-03 0.0857
    1.2000E-01   8.60000E-04 0.1078   4.60000E-04 0.1474   1.32000E-03 0.0870
    1.3000E-01   8.70000E-04 0.1072   4.60000E-04 0.1474   1.33000E-03 0.0867
    1.4000E-01   9.30000E-04 0.1036   5.20000E-04 0.1386   1.45000E-03 0.0830
    1.5000E-01   9.30000E-04 0.1036   4.30000E-04 0.1525   1.36000E-03 0.0857
    1.6000E-01   8.40000E-04 0.1091   5.90000E-04 0.1302   1.43000E-03 0.0836
    1.7000E-01   9.50000E-04 0.1025   5.90000E-04 0.1302   1.54000E-03 0.0805
    1.8000E-01   1.08000E-03 0.0962   6.70000E-04 0.1221   1.75000E-03 0.0755
    .
    .
    .
```

Plastic

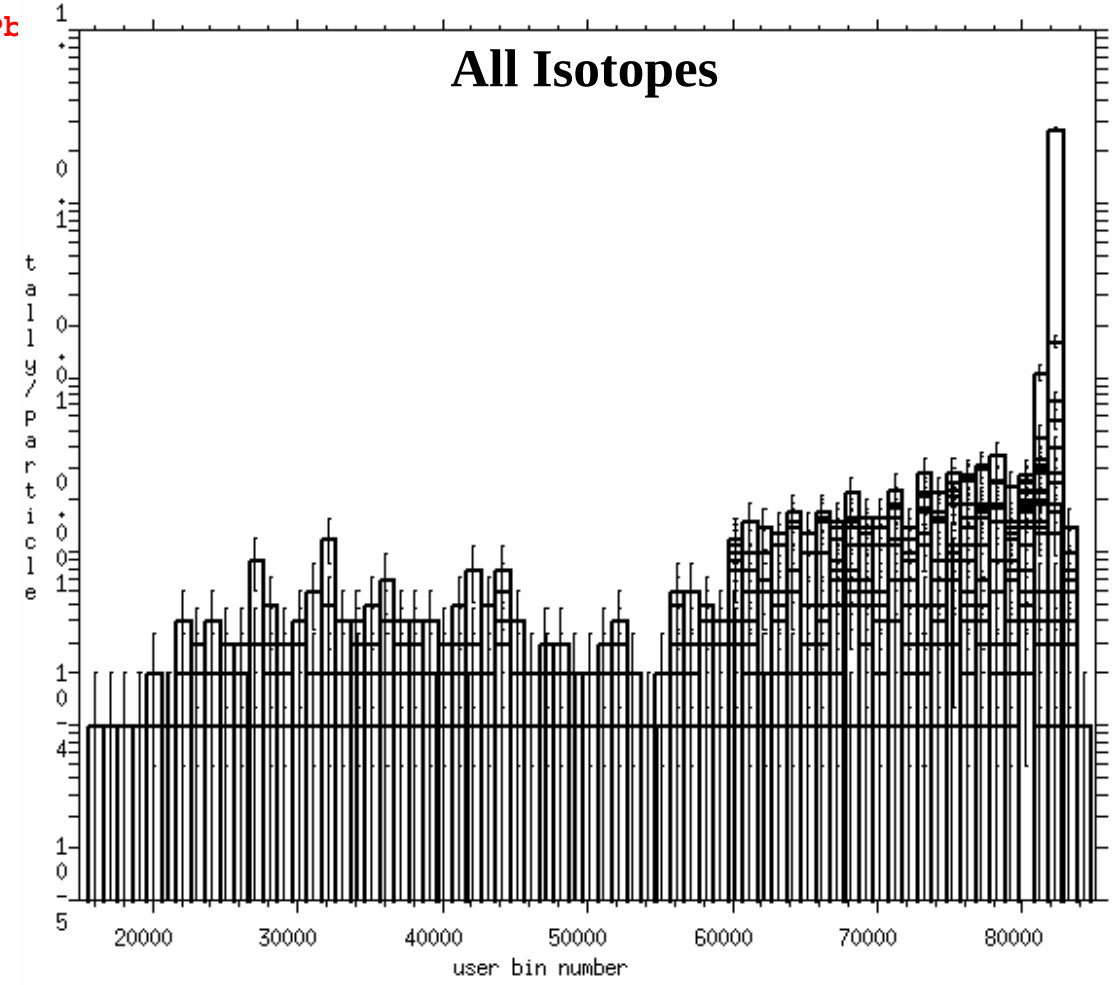
B G O

Anticoincidence Pulse-Height Tally

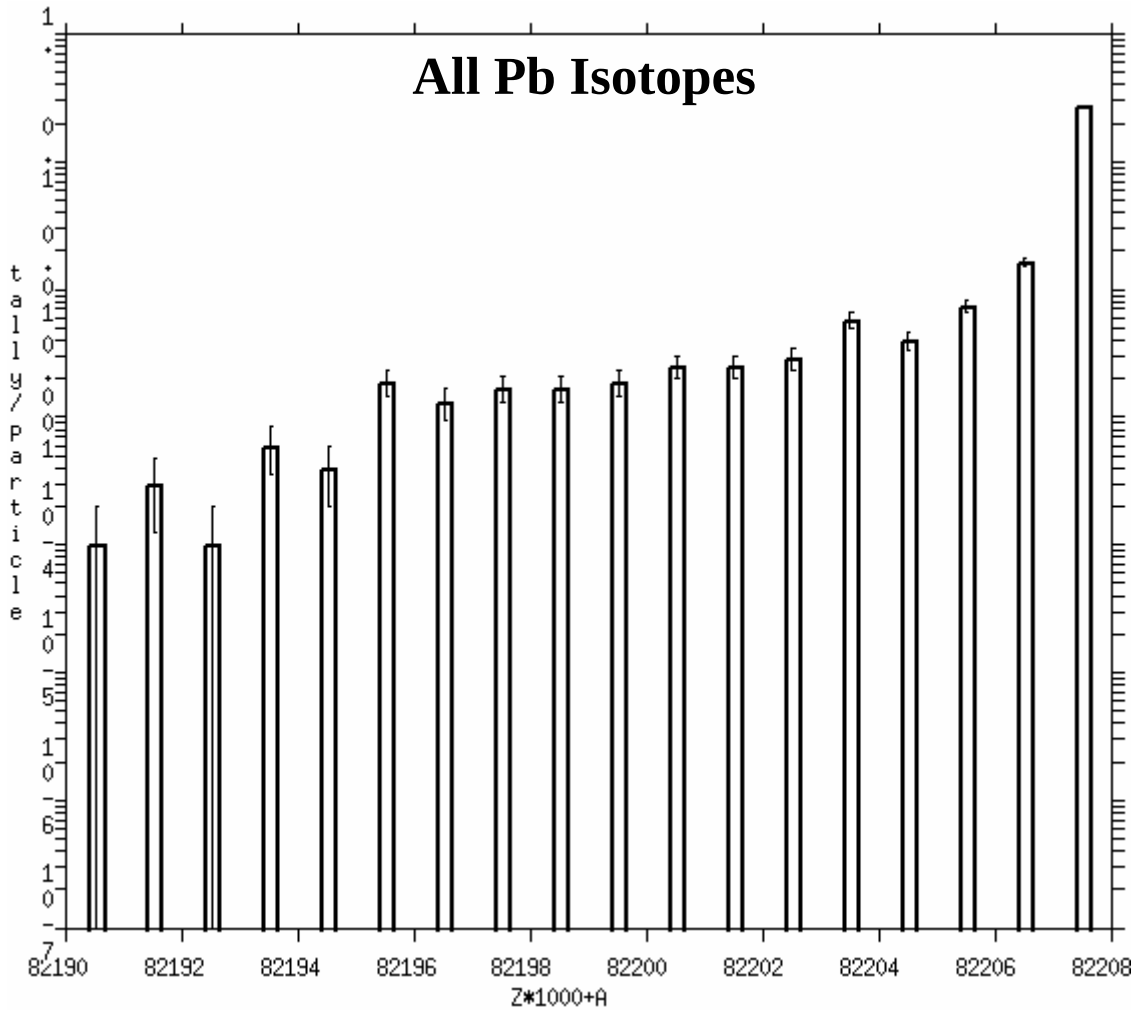


Residual Nuclei Pulse-Height Tally

```
Residuals for 1.2 GeV Protons => Pb
1 1 -11. -1 imp:h 1
2 0        1 imp:h 0

1 so .01

mode h n
sdef par h erg=1200
     vec 0 0 1 dir 1
m1 82208 1
phys:h 1300 j 0
phys:n 1300 3j 0
nps 10000
f8:h 1
ft8  RES 1 99
lca  7j -2 0
```



Residual Nuclei Pulse-Height Tally



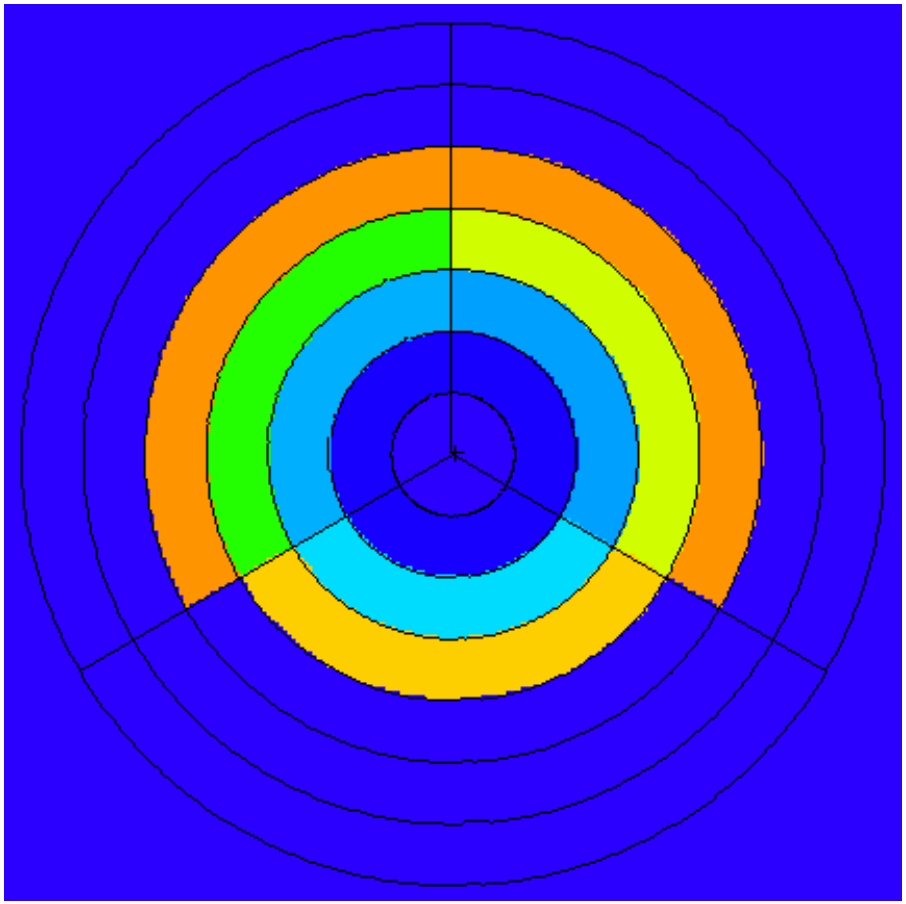
User-Interface Enhancements

- **Three new graphics options**
  - Lattice index labeling
  - WWG superimposed mesh plots
  - Color contour and mesh tally plots

WWG Superimposed Mesh Plots

```
Cylindrical WW Mesh-3 MeV Photons => H2O
1 1 1.0   -1  imp:p 1
2 0        1  imp:p 0

1 rcc 0 0 0  0 10 0  5

mode p
sdef sur=1.3 vec=0 1 0 dir=1 erg=3
m1 1001 2 8016 1
nps 1000000
f1:p 1.2
wwg 1 0
mesh geom=cyl origin=0 -1 0 ref=0 .1 0
     axs=0 1 0 vec=1 0 0
     imesh 6   iints 7
     jmesh 12  jints 7
     kmesh 1   kints 3
```

```
Cylindrical WW Mesh-3 MeV Photons => H2O
1 1 1.0   -1  imp:p 1
2 0        1  imp:p 0

1 rcc 0 0 0  0 10 0  5

mode p
sdef sur=1.3 vec=0 1 0 dir=1 erg=3
m1 1001 2 8016 1
nps 1000000
f1:p 1.2
wwg 1 0
mesh geom=cyl origin=0 -1 0 ref=0 .1 0
     axs=0 1 0 vec=1 0 0
     imesh 6   iints 14
     jmesh 12  jints 14
     kmesh 1   kints 6
wwp:p 4j -1
```

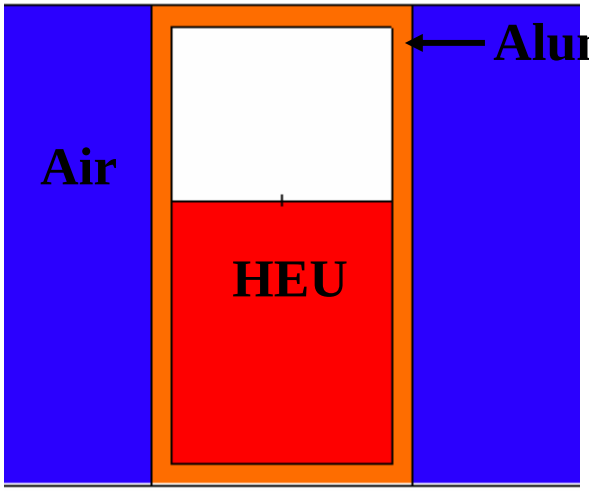


0	0	0	0	0	0	0
0	0	516.41	45.919	6.7298	.76013	.11743
0	798.41	115.65	12.151	2.0073	.29556	.078563
0	581.18	38.573	5.2054	.88906	.19987	.071571
0	152.11	11.927	1.9159	.51562	.16321	.067986
726.62	20.198	2.9409	.86014	.33905	.13782	.06476
4.3259	2.3747	1.0308	.48888	.24705	.12071	.062738
.5	.43165	.27975	.17564	.11279	.075209	.05309
729.93	20.787	2.9729	.88216	.33416	.13752	.064937
852.48	174.14	12.803	1.9784	.50913	.16225	.067529
971.61	365.37	65.745	5.6809	.89001	.20115	.071058
0	803.01	163.67	16.657	2.0451	.29261	.077905
0	0	255.6	64.384	7.2241	.69127	.11582
0	0	0	0	0	0	0

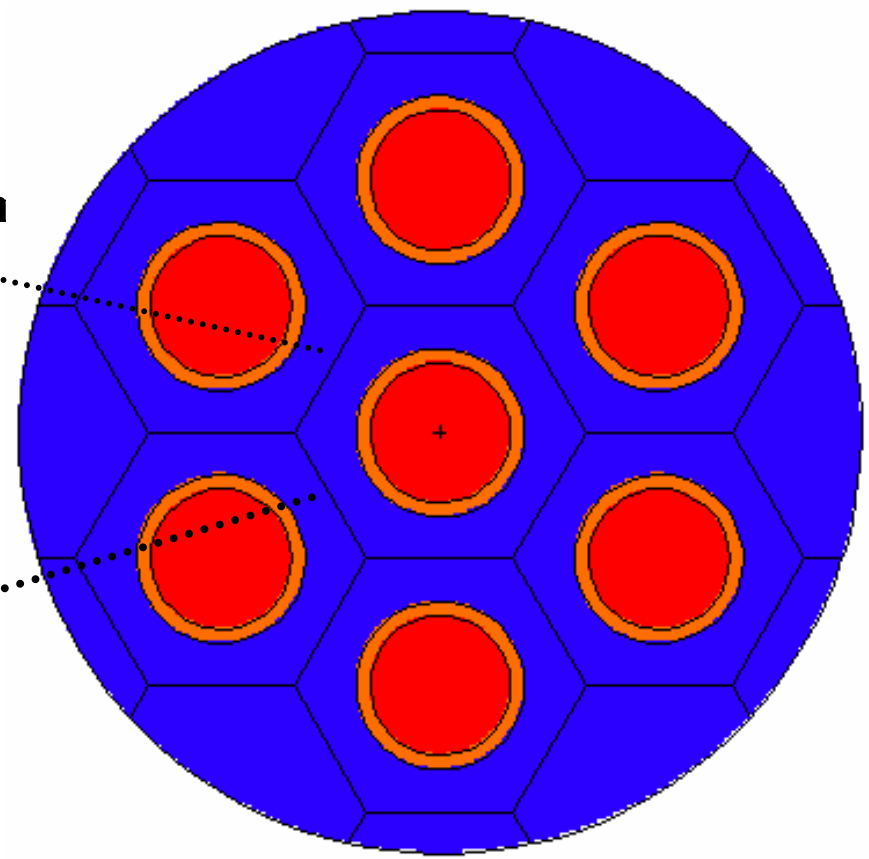
Color Contour and Mesh Tally Plots

```
HEU Cans in a Hex Lattice
1 1 -8.4       -1       u=1    imp:n=1
2 0            -2       u=1    imp:n=1
3 2 -2.7       -3 1 2   u=1    imp:n=1
4  3 -.001      3       u=1    imp:n=1
10 3 -.001     -6 lat=2 u=2    imp:n=1 fill=-2:2 -2:2 0:0
     2 2 2 2 2 2 2 1 1 2 2 1 1 1 2 2 1 1 2 2 2 2 2 2 2
11 0           -8              imp:n=1 fill=2
50 0            8              imp:n=0

1 rcc 0  0 0  0 12 0  5
2 rcc 0 12 0  0 8  0  5
3 rcc 0 -1 0  0 22 0  6
6 rhp 0 -1 0  0 22 0  9 0 0
8 rcc 0 -1 0  0 22 0  30

m1   1001 5.7058e-2 8016 3.2929e-2 92238 2.0909e-3  92235 1.0889e-4
m2   13027 1
m3   7014 .8 8016 .2
kcode 10000 1 10 40
ksrc 0 6 0   18 6 0   -18 6 0   9 6 15   -9 6 15   9 6 -15   -9 6 -15
tmesh
 rmesh12
 cora12  -30. 53i 30.
 corb12  0. 12.
 corc12  -30. 35i 30.
endmd
```

Color Contour and Mesh Tally Plots



~5% Enriched



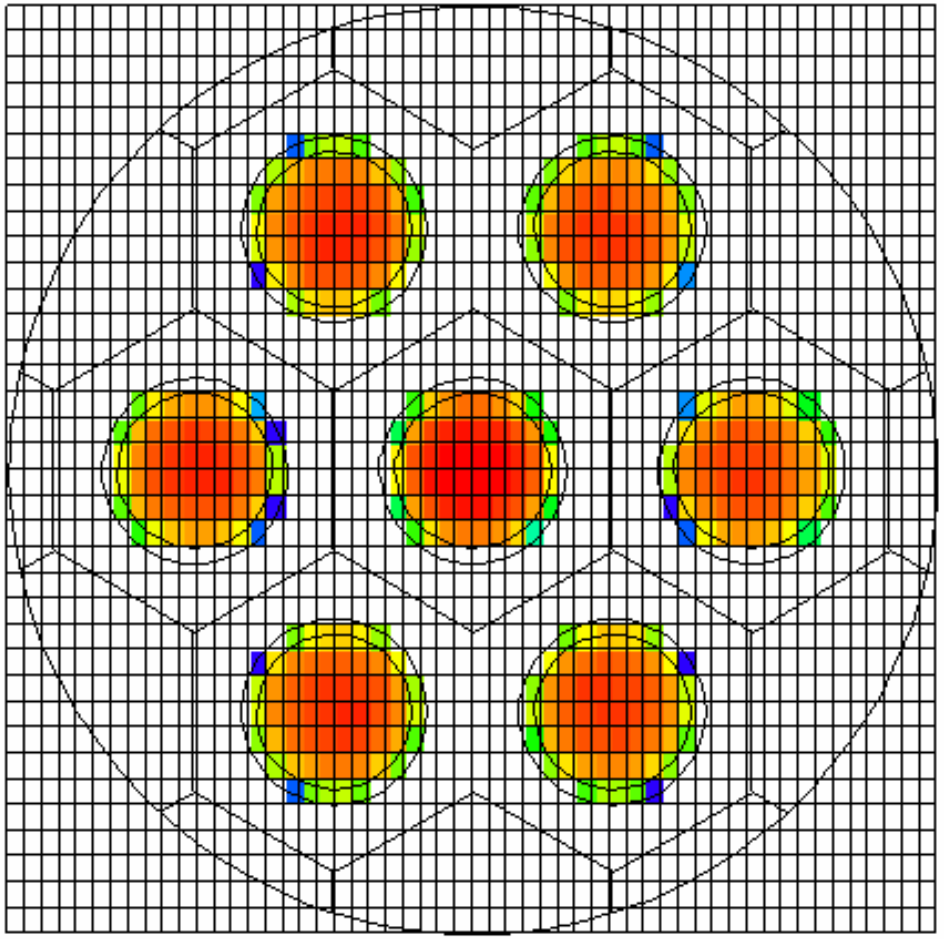
04/12/05 15:41:44
cylinders containing critical
fluid in macrobody hex lattice

probid = 04/11/05 16:42:09
basis: XZ
(1.000000, 0.000000, 0.000000)
(0.000000, 0.000000, 1.000000)
origin:
(0.00, 5.00, 0.00)
extent = (40.00, 40.00)

.

UP RT DN LF Origin .1 .2 Zoom 5. 10

cel
imp
rho
den
vol
fcl
mas
pwt
mat
tmp
wwn
ext
pd
dxc
u
lat
fill
ijk
nonu
pac
tal



Edit cel 1

Cell 1

xyz = 0.00, 5.00, 0.00

CURSOR SCALES 0 MT+Cell

PostScript ROTATE

COLOR tal12 LEVEL

XY YZ ZX

LABEL off off

MBODY on

PAR

N

Click here or picture or menu

Redraw Plot> End

User-Interface Enhancements

- **Three other miscellaneous improvements**
  - READ card
  - HISTP card extension
  - DXTRAN/Detector underflow control

User-Interface Enhancements

```
HEU Cans in a Hex Lattice
READ FILE=cells NOECHO

READ FILE=surfaces

m1    1001 5.7058e-2   8016 3.2929e-2
     92238 2.0909e-3  92235 1.0889e-4
m2   13027 1
m3   7014 .8 8016 .2
kcode 10000 1 10 40
ksrc  0 6 0   18 6 0   -18 6 0   9 6 15
     -9 6 15   9 6 -15   -9 6 -15
tmesh
 rmesh12
 cora12  -30. 53i 30.
 corb12  0. 12.
 corc12  -30. 35i 30.
endmd
```

File "cells"

```
1 1 -8.4      -1      u=1    imp:n=1
2 0           -2      u=1    imp:n=1
3 2 -2.7      -3 1 2  u=1    imp:n=1
4  3 -.001     3      u=1    imp:n=1
10 3 -.001    -6 lat=2 u=2   imp:n=1
     fill=-2:2 -2:2 0:0
          2 2 2 2 2
          2 2 1 1 2
          2 1 1 1 2
          2 1 1 2 2
          2 2 2 2 2
11 0          -8             imp:n=1 fill=2
50 0           8             imp:n=0
```

File "surfaces"

```
1 rcc 0  0 0  0 12 0  5
2 rcc 0 12 0  0 8  0  5
3 rcc 0 -1 0  0 22 0  6
6 rhp 0 -1 0  0 22 0  9 0 0
8 rcc 0 -1 0  0 22 0  30
```

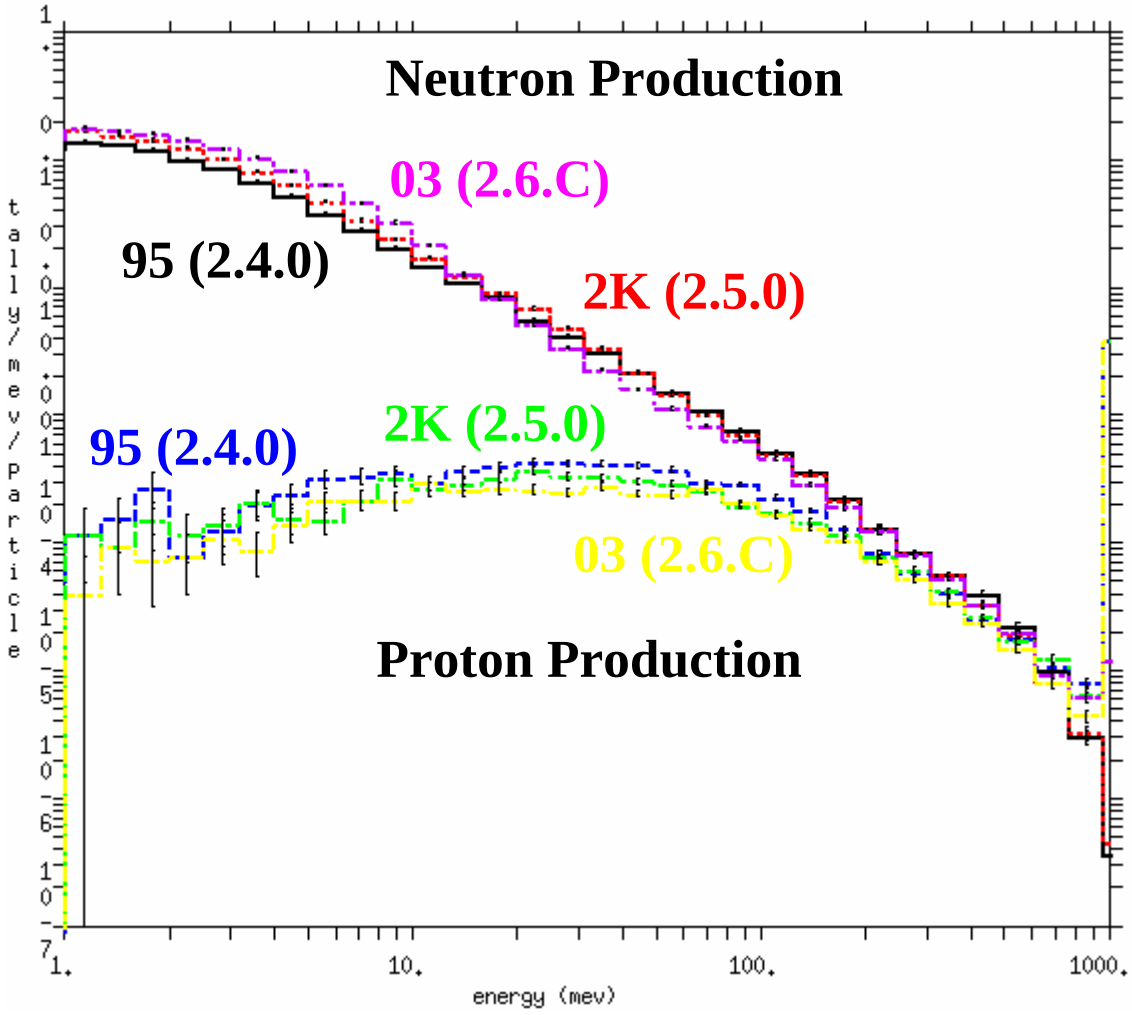
Physics Enhancements

- **Four model physics improvements**
  - Mix & match of libraries and models
  - CEM upgrade to version 2K
  - INCL 4/ABLA physics models
  - Secondary-particle production

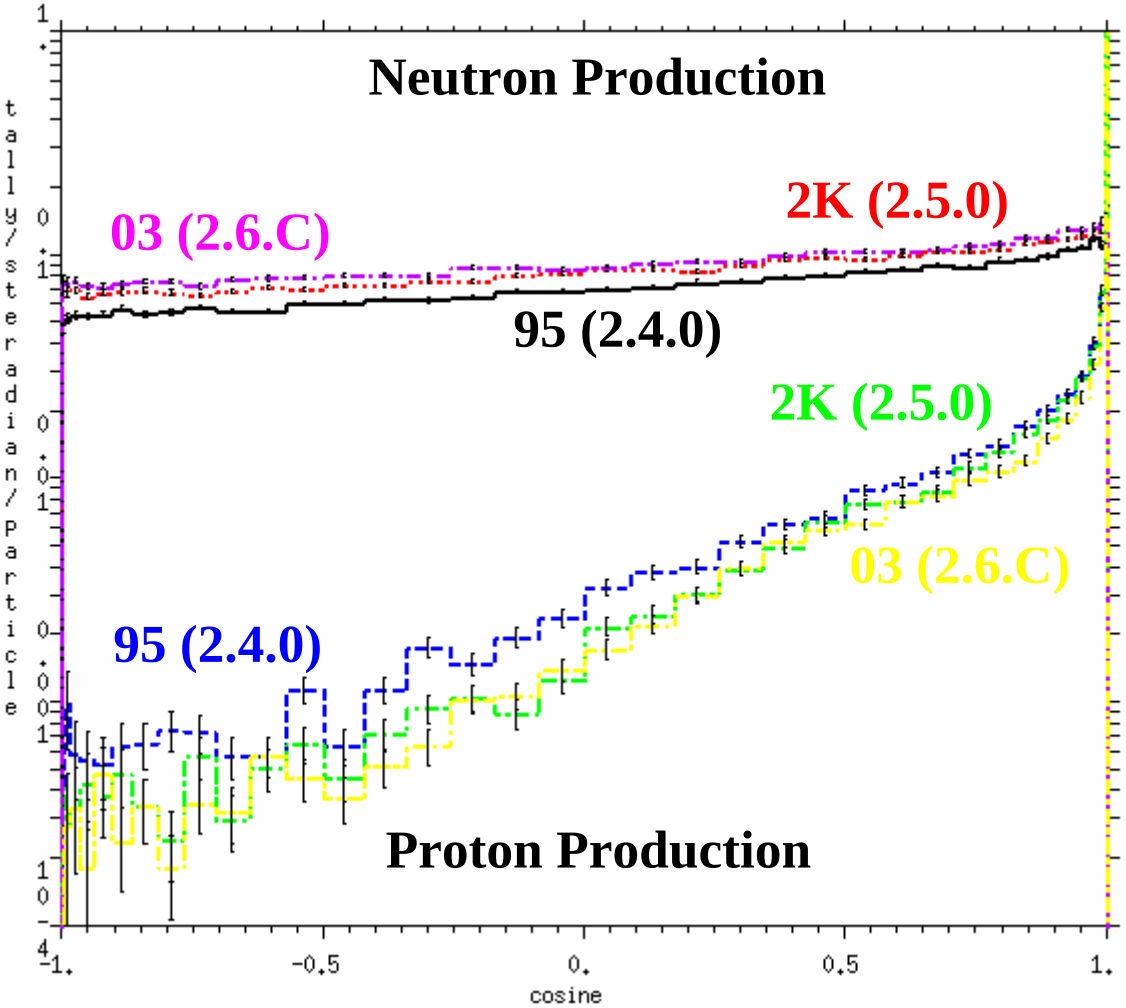
CEM Upgrade (versions 95, 2K, 03)

```
CEM for 1.2 GeV Protons => Pb
1 1 -11. -1 imp:h 1
2 0       1 imp:h 0

1 so 1.0

mode h n
sdef par=h erg=1200 vec=1 0 0 dir=1
m1 82208 1
phys:h 1300 j 1
phys:n 1300 3j 1
nps 100000
lca    8j 1
f1:n   1
ft1    frv 1 0 0
*c1    175 34i 0
f11:n  1
e11    1. 30log 1200.
f21:h  1
ft21   frv 1 0 0
*c21   175 34i 0
f31:h  1
e31    1. 30log 1200.
```

CEM Upgrade (versions 95, 2K, 03)



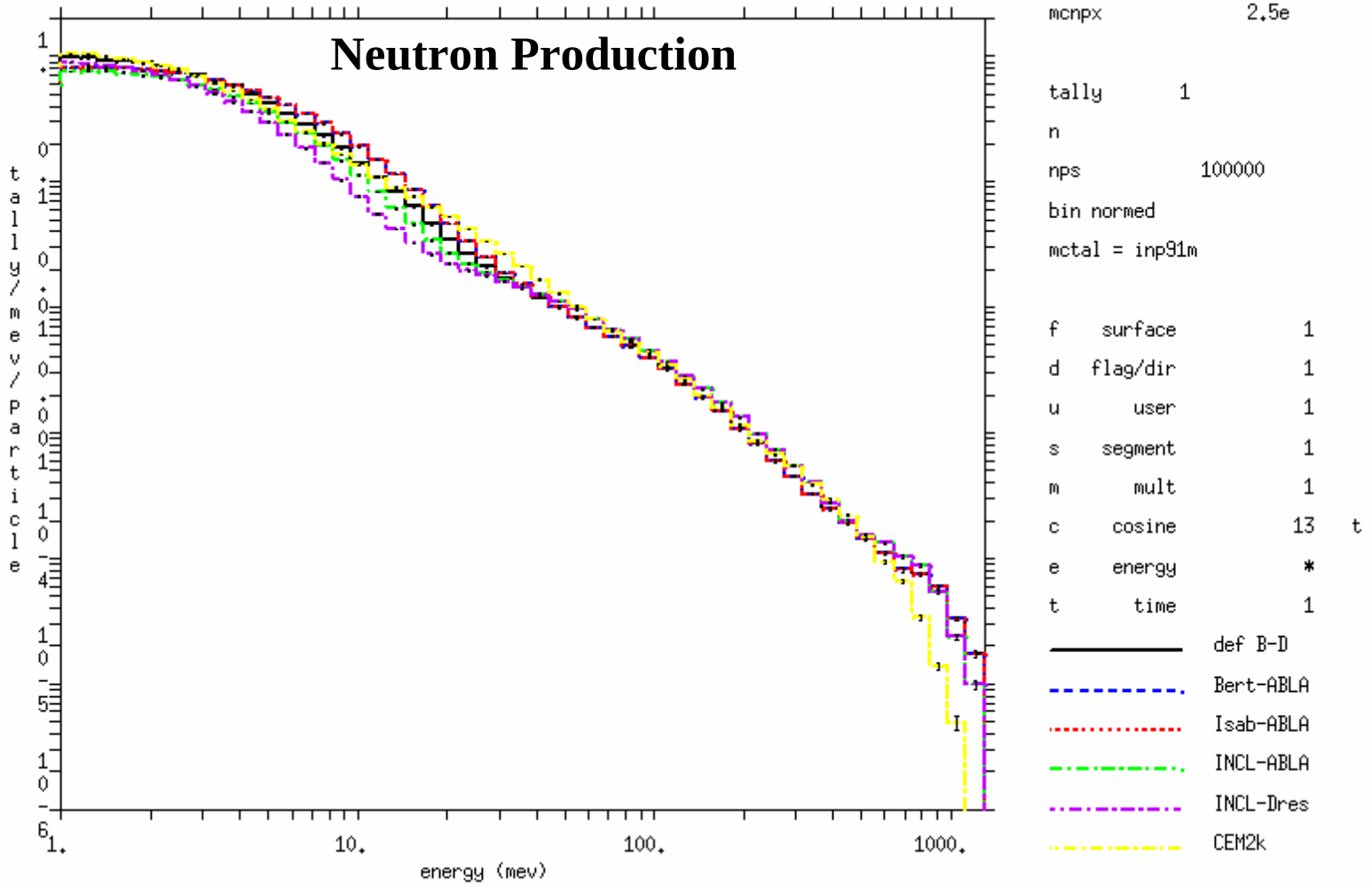
CEM Upgrade (versions 95, 2K, 03)



INCL 4/ABLA Physics Models

```
Various Physics Models for 1.2 GeV Protons => Pb
1 1 -11. -1 imp:h 1
2 0       1 imp:h 0

1 so .01

mode h n
sdef par h erg=1200 vec 0 0 1 dir 1
m1 82208 1
phys:h 1300 j 0
phys:n 1300 3j 0
nps 100000
f1:n  1
ft1   frv 0 0 1
*c1   167.5 9i 17.5 0 T
e1    1 50log 1300
LCA   7j -2 0     $ Bertini/Dresner

LCA   7j -2 0     $ Bertini/ABLA
LEA   6J  2
LCA   2j  2 4j -2 $ ISABEL/Dresner
LCA   2j  2 4j -2 $ ISABEL/ABLA
LEA   6J  2
LCA   7j -2 2     $ INCL4/ABLA
LEA   6j  2
LCA   7j -2 2     $ INCL4/Dresner
LCA   7j -2 1     $ CEM2K
```

Secondary-Particle Production



Physics Enhancements

- **Two neutron physics improvements**
  - Fission multiplicity
  - S(α,β) secondary-energy smoothing

Fission Multiplicity

```
Pu-239 Fission Multiplicity in H2O
1  1 -1.0   -1    imp:n=1
2  0         1    imp:n=0

1 SPH 0 0 0 100

sdef  par=sf pos=0 0 0 rad=d1 axs=0 0 1 ext=0
si1   0 90
sp1   -21 1
m1    1001 2 8016 1 94239 1.e-4
phys:n 5j -1
nps  100000
```

Fission Multiplicity

1spontaneous fission source multiplicity and moments. print table 117

	by number			by weight			
	fissions	fission neutrons	multiplicity fraction	fissions	fission neutrons	multiplicity fraction	error
nu = 0	1232	0	7.84464E-02	3.62012E-02	0.00000E+00	7.84464E-02	0.0280
nu = 1	3344	3344	2.12926E-01	9.82605E-02	9.82605E-02	2.12926E-01	0.0164
nu = 2	5134	10268	3.26902E-01	1.50858E-01	3.01716E-01	3.26902E-01	0.0129
nu = 3	3984	11952	2.53677E-01	1.17066E-01	3.51199E-01	2.53677E-01	0.0149
nu = 4	1627	6508	1.03598E-01	4.78079E-02	1.91232E-01	1.03598E-01	0.0242
nu = 5	345	1725	2.19675E-02	1.01375E-02	5.06876E-02	2.19675E-02	0.0536
nu = 6	38	228	2.41961E-03	1.11660E-03	6.69958E-03	2.41961E-03	0.1621
nu = 7	1	7	6.36740E-05	2.93841E-05	2.05689E-04	6.36740E-05	1.0000
total	15705	34032	1.00000E+00	4.61477E-01	1.00000E+00	1.00000E+00	0.0059

factorial moments	by number		by weight	
nu	2.16695E+00	0.0044	2.16695E+00	0.0044
nu(nu-1)/2!	1.96683E+00	0.0093	1.96683E+00	0.0093
nu(nu-1)(nu-2)/3!	9.38364E-01	0.0176	9.38364E-01	0.0176
nu(nu-1) .... (nu-3)/4!	2.51958E-01	0.0349	2.51958E-01	0.0349
nu(nu-1) .... (nu-4)/5!	3.78223E-02	0.0777	3.78223E-02	0.0777
nu(nu-1) .... (nu-5)/6!	2.86533E-03	0.2071	2.86533E-03	0.2071
nu(nu-1) .... (nu-6)/7!	6.36740E-05	1.0000	6.36740E-05	1.0000

Fission Multiplicity

1spontaneous and induced fission multiplicity and moments. print table 117

	by number			by weight			
	fissions	fission neutrons	multiplicity fraction	fissions	fission neutrons	multiplicity fraction	error
nu = 0	1499	0	5.39713E-02	3.95528E-02	0.00000E+00	6.50562E-02	0.0261
nu = 1	4627	4627	1.66595E-01	1.13595E-01	1.13595E-01	1.86840E-01	0.0145
nu = 2	8169	16338	2.94124E-01	1.87902E-01	3.75804E-01	3.09060E-01	0.0105
nu = 3	7844	23532	2.82422E-01	1.63875E-01	4.91624E-01	2.69540E-01	0.0110
nu = 4	4200	16800	1.51221E-01	7.89230E-02	3.15692E-01	1.29812E-01	0.0162
nu = 5	1212	6060	4.36379E-02	2.06316E-02	1.03158E-01	3.39348E-02	0.0316
nu = 6	208	1248	7.48902E-03	3.28351E-03	1.97011E-02	5.40070E-03	0.0762
nu = 7	13	91	4.68064E-04	1.91773E-04	1.34241E-03	3.15428E-04	0.2943
nu = 8	2	16	7.20098E-05	2.50905E-05	2.00724E-04	4.12687E-05	0.7174
total	27774	68712	1.00000E+00	6.07979E-01	1.42112E+00	1.00000E+00	0.0035

factorial moments	by number		by weight	
nu	2.47397E+00	0.0030	2.33744E+00	0.0034
nu(nu-1)/2!	2.60927E+00	0.0064	2.32469E+00	0.0069
nu(nu-1)(nu-2)/3!	1.49388E+00	0.0118	1.24950E+00	0.0124
nu(nu-1) .... (nu-3)/4!	5.03168E-01	0.0226	3.94425E-01	0.0231
nu(nu-1) .... (nu-4)/5!	1.02434E-01	0.0502	7.52740E-02	0.0492
nu(nu-1) .... (nu-5)/6!	1.27817E-02	0.1382	8.76422E-03	0.1290
nu(nu-1) .... (nu-6)/7!	1.04414E-03	0.4094	6.45578E-04	0.3940

Physics Enhancements

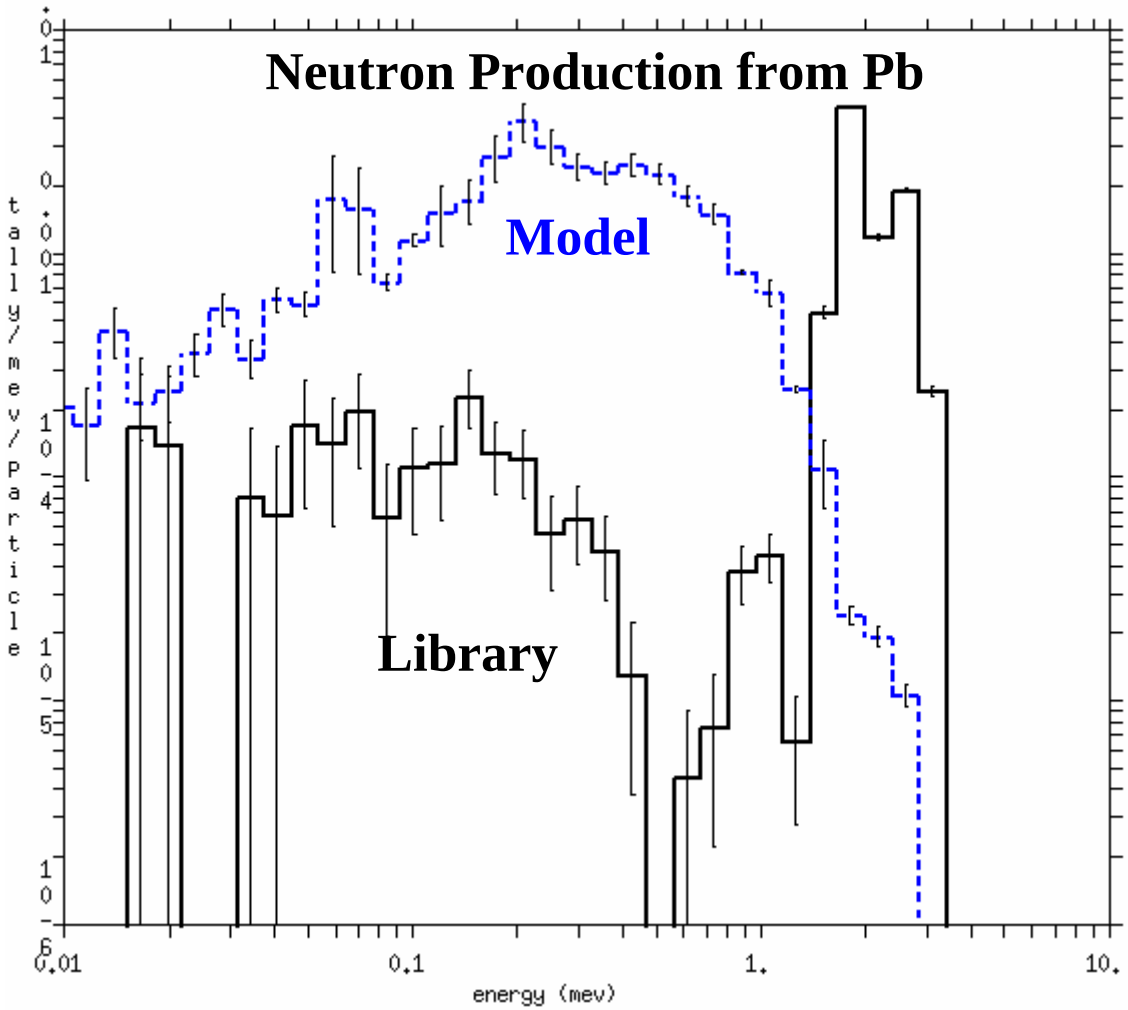
- **Three photon physics improvements**
  - Photonuclear physics model
  - Photon Doppler broadening
  - Variance reduction with pulse-height tallies

Photonuclear Physics Model

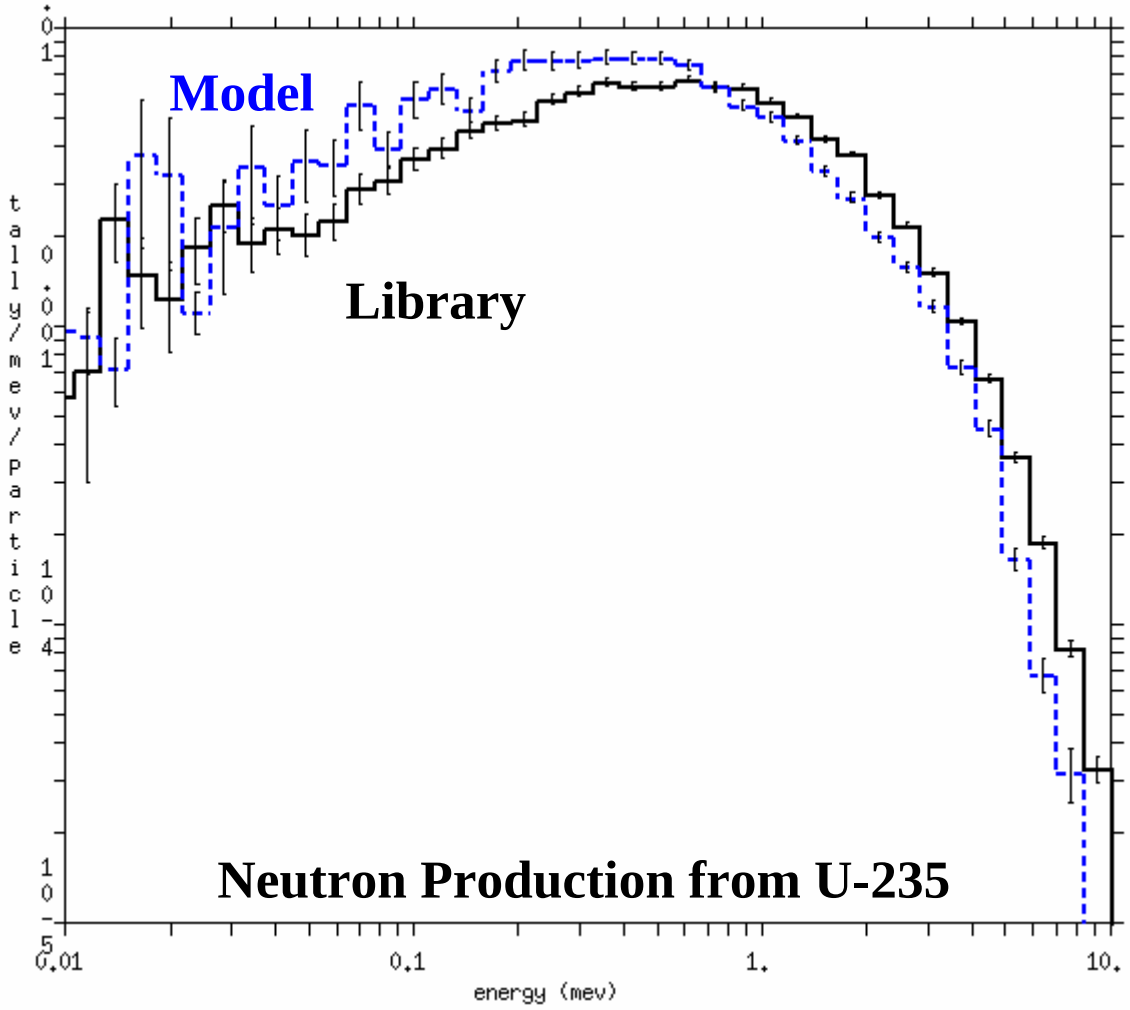
```
Photonuclear 10 MeV Photons => Pb
1  1 -7.86   -1    imp:n=1
2  0          1    imp:n=0

1 SPH 0 0 0 2

mode   n p
sdef   par=p erg=10.0
phys:p 3j 1
m1     82208 1
c    mx1:p  model
nps    1000000
f1:n   1
e1     1e-3 50log 10.
```

```
Photonuclear 10 MeV Photons => U-235
1  1 -7.86   -1    imp:n=1
2  0          1    imp:n=0

1 SPH 0 0 0 2

mode   n p
sdef   par=p erg=10.0
phys:p 3j 1
m1     92235 1
xs1 92235.27u 233.024994 bofod01u 0 1 54868 2946 0 0 0.0
c    mx1:p  model
nps    1000000
f1:n   1
e1     1e-3 50log 10.
```

Photonuclear Physics Model



Photonuclear Physics Model



Infrastructure Enhancements

- **8-byte integers**
  - Users can now run billions of particles
  - Often required for parallel calculations
  - Runs about 20% slower on most systems
- **Support for new compilers**
  - Mac OS X with IBM compiler
  - Windows PC and Linux with Intel compiler
- **Parallel processing with MPI**
  - PVM option is still available
- **MPI speedup for criticality problems**
  - Eliminates collection of fission source after each cycle

Outline

- **MCNPX Summary and Development History**
- **User Base, Web Site, Development Philosophy**
- **Physics and Capability Details**
- **Select 2.5.0 Features**
- **Future Development**

Future Development

- **MCNP 6 and MCNPX 2.6.B merger project**
  - Preserve all capabilities of both codes
  - Complete merger within one year
  - Release merged code as MCNP 6 or MCNP 7
  - MCNPX final version likely 2.6.0
- **Features beyond version 2.6.0**
  - Non-uniform electric and magnetic fields
  - Coupling of secondary particles for library interactions
  - Direct CAD links with spline surface tracking
  - Enhanced visualization tools