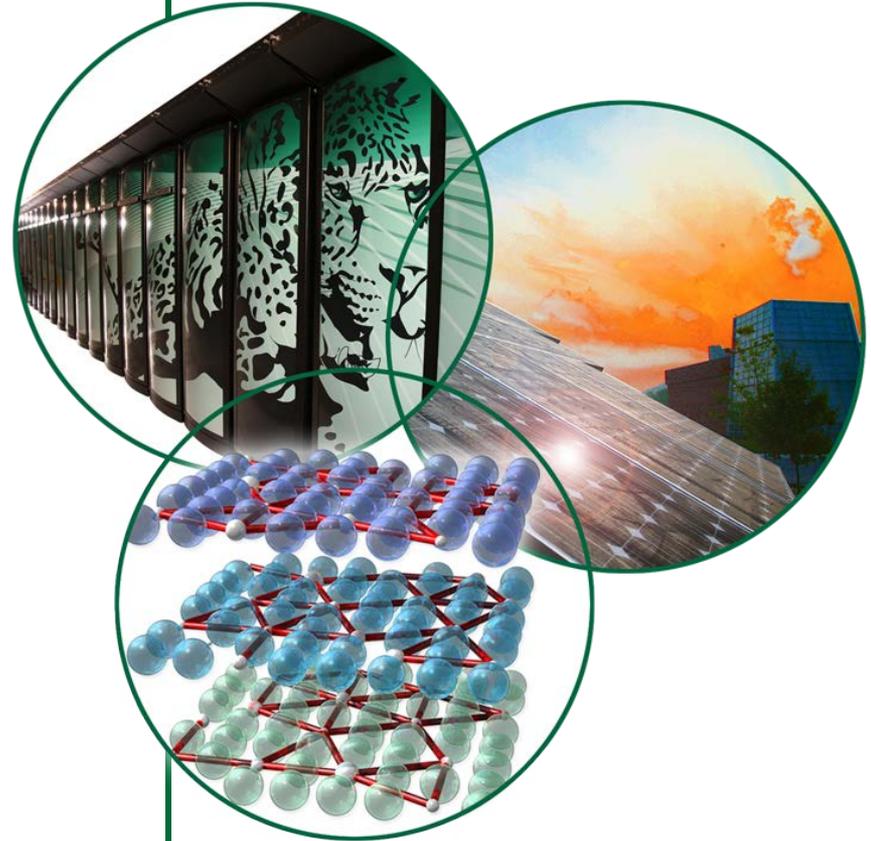
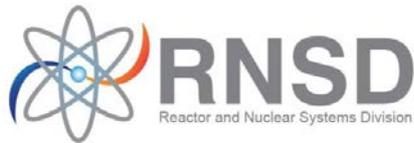


# ORIGEN Tutorial

## Fast, Easy, and Accurate Fuel Depletion, Decay and Source Term Analysis

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# ORIGEN Structure

- **ORIGEN has three main components:**
  - ARP code
    - interpolate on a set of pre-generated burnup-dependent cross sections to obtain cross sections for use with ORIGEN-S
  - ORIGEN-S code
    - perform depletion and decay simulations
  - OPUS/PlotOPUS codes
    - extract and plot the calculated results
- **Also called ORIGEN-ARP**

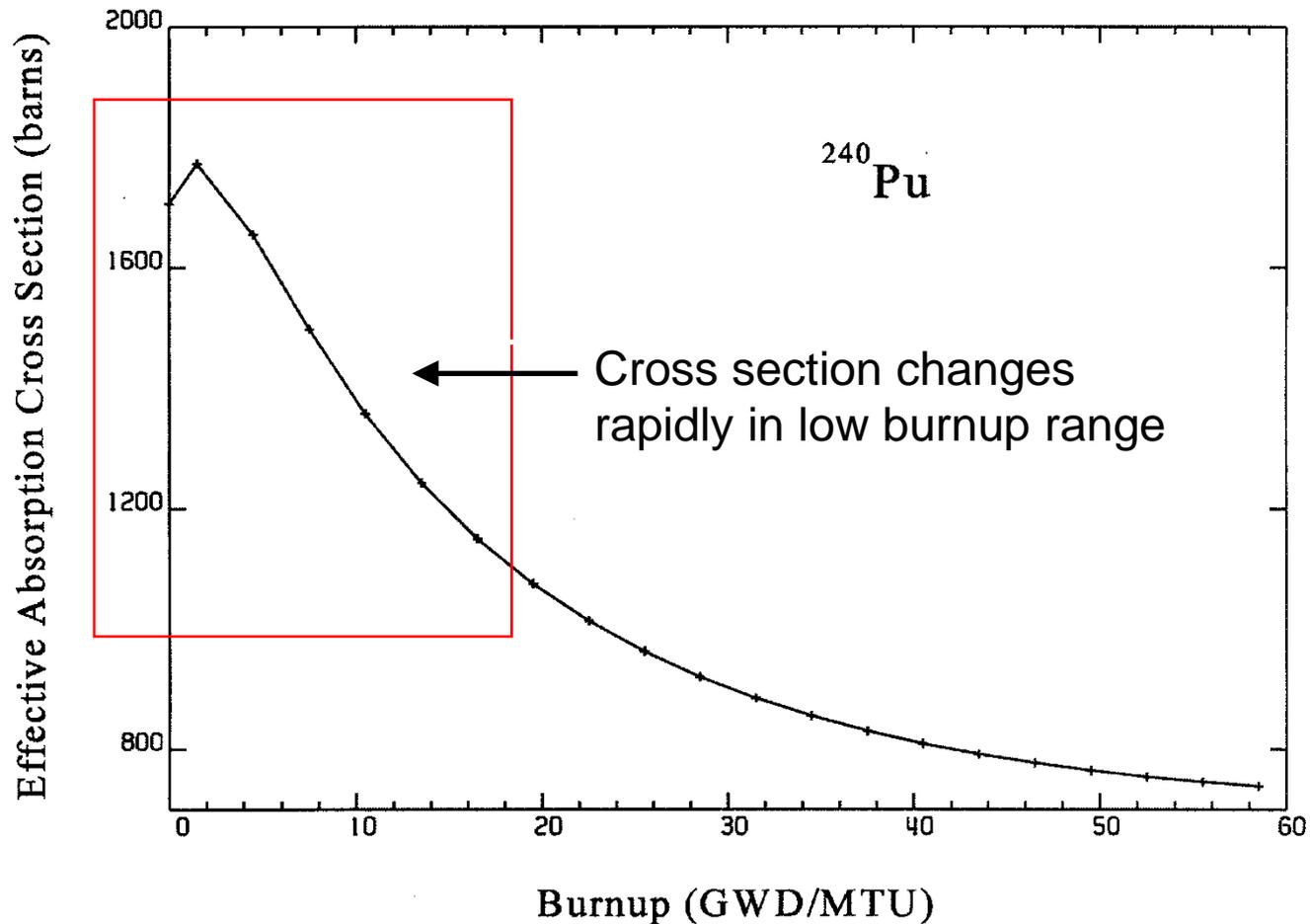
# ORIGEN Methodology

- Easy-to-use Windows input offers two options:
  - Origen Express form
  - Detail Input form
- Uses multi-burnup libraries that have been pre-generated for specific reactor fuel assembly designs
  - TRITON 2-D models used to generate most libraries
  - there is one library for each fuel enrichment / moderator density combination

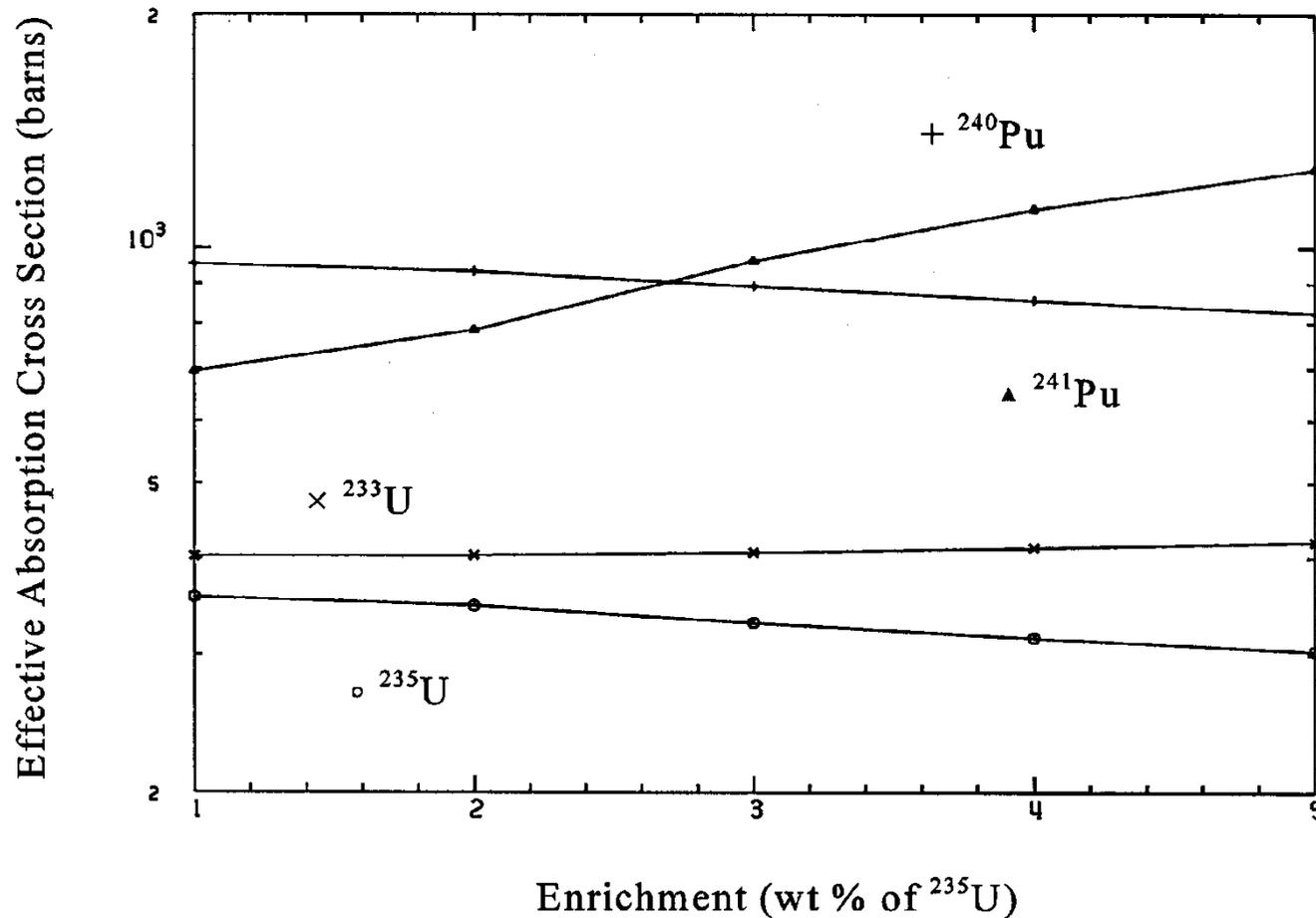
# ORIGEN Methodology (cont.)

- ARP (Automated Rapid Processing) interpolates pre-generated cross-section libraries
- Interpolation parameters for uranium fuels
  - Burnup
  - Enrichment
  - Moderator density (optional)
- MOX interpolation parameters
  - Total Pu content
  - $^{239}\text{Pu}$  concentration
  - Burnup
  - Moderator density
- Accuracy of original models maintained

# Cross-section interpolation strategy: $^{240}\text{Pu}$ absorption cross section vs burnup



# Cross-section interpolation strategy: variation with enrichment is nearly linear

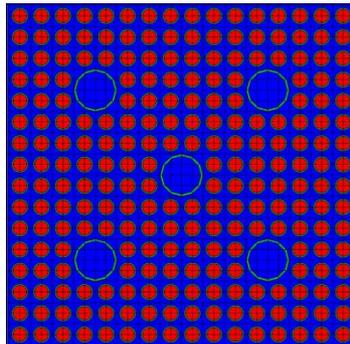


# ORIGEN Libraries (PWR)

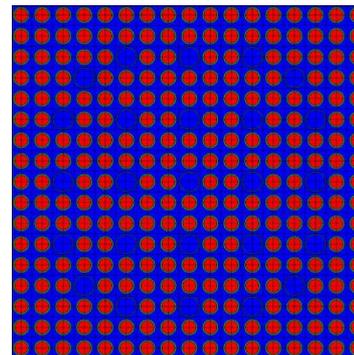
Assembly Design	Library Name	Enrichment (wt% U-235)	Density (g/cc)
Westinghouse CE 14x14	ce14x14	1.5 – 6.0	0.7332
Westinghouse CE 16x16	ce16x16	1.5 – 6.0	0.7100
Westinghouse 14x14	w14x14	1.5 – 6.0	0.7264
Siemens 14x14	s14x14	1.5 – 6.0	0.7283
Westinghouse 15x15	w15x15	1.5 – 6.0	0.7135
Westinghouse 17x17	w17x17	1.5 – 6.0	0.6700
Westinghouse 17x17 OFA	w17x17_ofa	1.5 – 6.0	0.6700

These libraries are based on 2-D TRITON models with burnups to 72 GWd/MTU.

**CE 16x16**



**W 17x17**

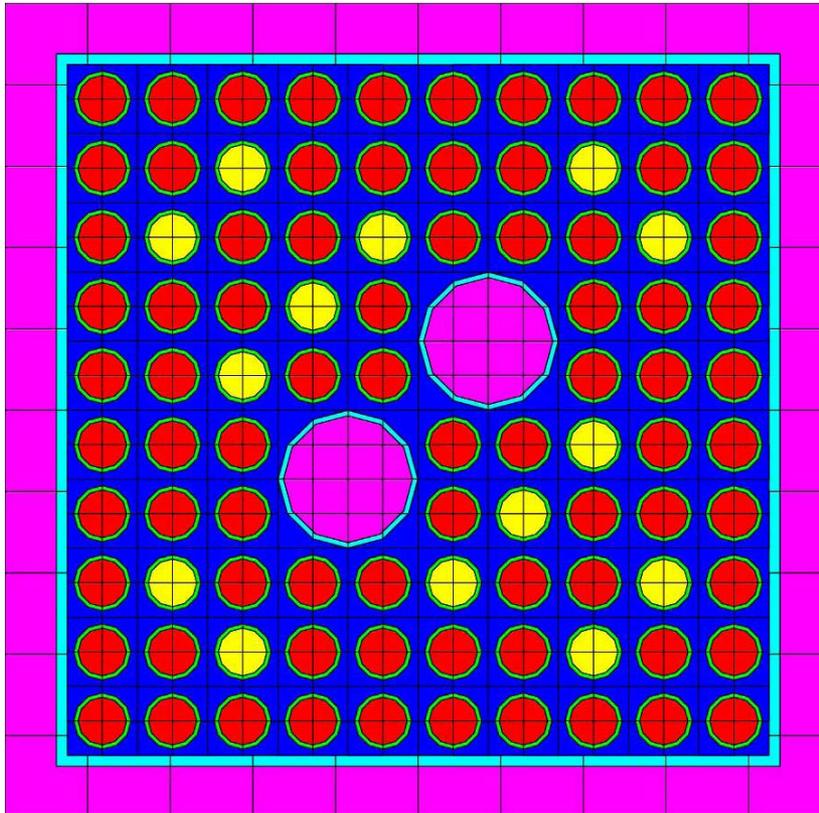


# ORIGEN Libraries (BWR)

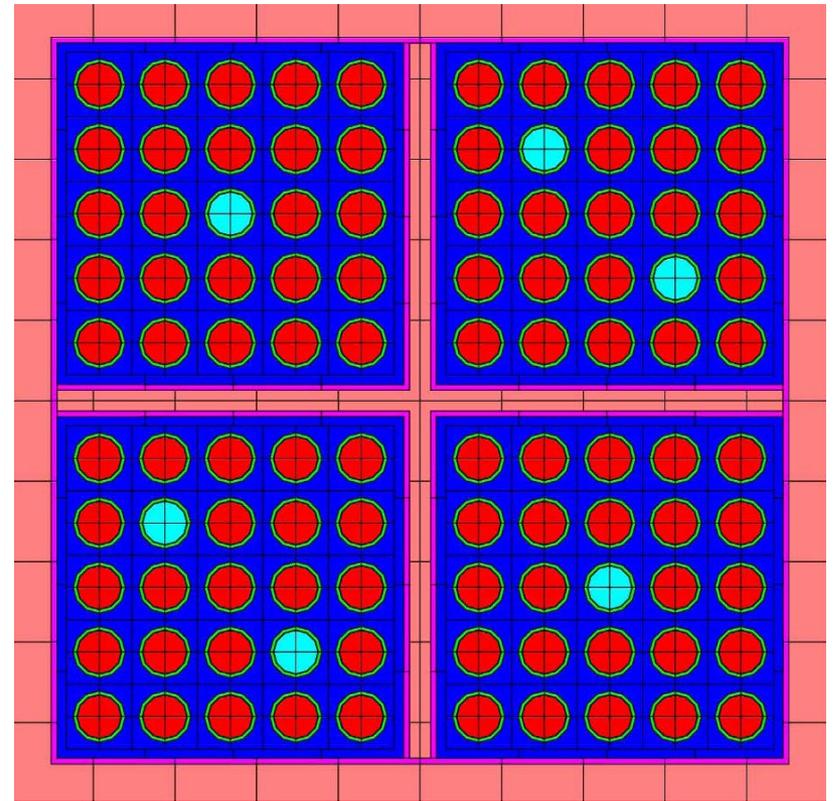
<b>Assembly Design</b>	<b>Library Name</b>	<b>Enrichment (wt% U-235)</b>	<b>Density (g/cc)</b>
GE 7x7	ge7x7-0	1.5 – 6.0	0.1 – 0.9
GE 8x8	ge8x8-4	1.5 – 6.0	0.1 – 0.9
ABB 8x8	abb8x8-1	1.5 – 6.0	0.1 – 0.9
GE 9x9	ge9x9-7	1.5 – 6.0	0.1 – 0.9
GE 10x10	ge10x10-8	1.5 – 6.0	0.1 – 0.9
ATRIUM-9	atrium9-9	1.5 – 6.0	0.1 – 0.9
ATRIUM-10	atrium10-9	1.5 – 6.0	0.1 – 0.9
SVEA-64	svea64-1	1.5 – 6.0	0.1 – 0.9
SVEA-100	svea100-0	1.5 – 6.0	0.1 – 0.9

These libraries are based on 2-D TRITON models with burnups to 72 GWd/MTU.

# ORIGEN Libraries (BWR)



**GE 10x10**



**SVEA-100**

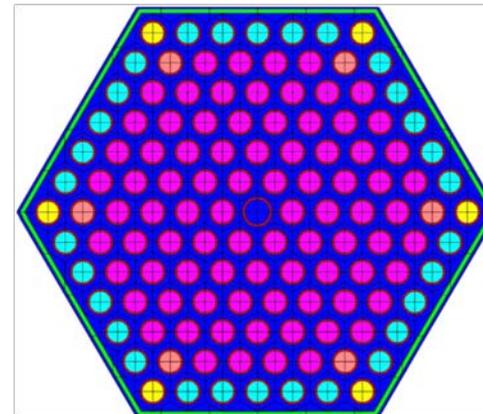
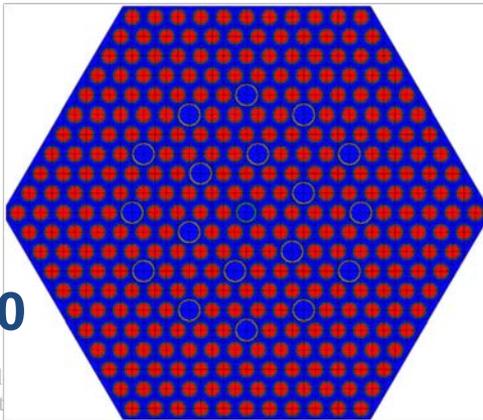
**Assembly models**

# ORIGEN Libraries (VVER)

Assembly Design	Library Name	Enrichment (wt% U-235)	Density (g/cc)
VVER-440 flat	vver440(3.6)	1.6 – 3.6	0.75
VVER-440 profiled	vver440(3.82)	3.82 average	0.75
VVER-440 profiled	vver440(4.25)	4.25 average	0.75
VVER-440 profiled	vver440(4.38)	4.38 average	0.75
VVER-1000	vver1000	1.5 – 6.0	0.7145

These libraries are based on 2-D TRITON models with burnups to 72GWd/MTU.

**VVER-1000**



**VVER-440**



# Other ORIGEN Libraries

- CANDU reactor (natural  $\text{UO}_2$ )
- MAGNOX (natural U metal)
- Advanced Gas-Cooled Reactor (AGR)
- MOX fuels (PWR and BWR assemblies)
  - 8x8-2, 9x9-9, 9x9-1, 10x10-9
  - 14x14, 15x15, 16x16, 17x17, 18x18
  - Variable moderator density for all BWR MOX designs

These libraries are based on 1-D SAS2 models.

# ORIGEN Modes of Operation

- Express – used for calculations with minimal input data required
  - LEU or MOX fuel type
  - Enrichment (or MOX fuel specifications)
  - Burnup
  - Average power
  - Number of reactor cycles
  - % uptime/downtime
- Detail – when assembly dependent operating history detail is required, or additional composition or plotting information is needed

# Tool Bar Buttons



- Open existing file (express file / detail file)



- Save case (express or detail - .uo2 / .mox / .arp)



- Execute problem (via SCALE) (if grayed out, run window is likely open, or Setup incomplete)



- ❖ Launch editor to view / modify text input file



- ❖ Launch editor to view output



- ❖ Launch editor to view / edit plot data table(s)



- ❖ Launch PlotOPUS interactive plotting program



- ❖ Hop to Express input form

# ORIGEN-ARP Express Form (UO<sub>2</sub>)

The screenshot shows the OrigenArp software interface. The title bar reads "OrigenArp". The menu bar includes "File", "Edit", "View", and "Help". The toolbar contains icons for "Options", "new", "open", "save", "print", "help", "run", "output", "plot", "tables", "editor", and "detail". Below the toolbar is a "Plot Setup" section with buttons for "OK", "Apply", "Reset", "Close", and "MOX".

The main workspace contains the following fields and controls:

- Title:
- Fuel Type:
- Uranium (g):
- Enrichment (wt%U235):  (1.5 to 5)
- Burnup (MWd/MTU):
- Cycles:
- Libraries:  Per Cycle
- Cooling Time:
- Moderator Density (g/cc):

On the right side, there is a "Power History" section with a horizontal bar chart showing a single bar at 95% Up. Below it, the "Average Power" is  MW/MTU.

Decorative elements include the chemical formula "UO<sub>2</sub>" and an image of a train labeled "Express".

The status bar at the bottom left shows "Ready" and the bottom right shows "NUM".

# Plotting and Visualization

- Plot files are created by OPUS module (ORIGEN-S Post-Process Utility for SCALE)
- Extracts and formats ORIGEN-S results for plotting
  - most important or selected nuclides for a parameter of interest (e.g., radioactivity, decay heat, mass) vs time
  - compare results from different cases vs time
  - neutron and gamma spectra at selected decay times

# ORIGEN-ARP Plot Setup

**PlotOPUS Case Input**

first last prev next ok copy new clear delete import help cancel

Select Plot: 2

Case Type:  Decay  Irradiation

Plot Type:  Nuclides  Total Neutron Spectra  
 Elements  (Alpha, n) Reactions  
 Gamma Spectra  Spontaneous Fission

Case(s) to Plot: 6 Decay - Cycle 3 Down - OEC

Output Units: Atoms/b-cm

Library Type: ALL

Fuel Volume: 108568.760000

Nuclides to Plot (Optional)

Available	Selected
Ac-225	
Ac-227	
Ac-228	
Ag-106	
Ag-107	
Ag-108	
Ag-108M	
Ag-109	
Ag-109M	
Ag-110	
Ag-110M	
Ag-111	

Only plot selected nuclides

Import Nuclides

Import Nuclides will read the first list of nuclides from a selected input file with an opus datablock.

# OPUS Plot Options

## OUTPUT UNITS=

GRAMS  
GRAM ATOMS  
CURIES  
BEQUERELS  
KILOGRAMS  
ATOM%  
WT%  
TOTAL WATTS  
GAMMA WATTS  
ATOMS/B-CM\*  
GRAMS/CM3\*  
ABSORPTIONS  
TOXICITY IN AIR  
TOXICITY IN WATER

## LIBRARY TYPE=

LIGHT ELEMENTS  
ACTINIDES  
FISSION PRODUCTS  
ACT AND F.P.  
ALL

## CASE TYPE=

IRRADIATION or  
DECAY

## PLOT TYPE=

NUCLIDES  
ELEMENTS  
GAMMA SPECTRA  
TOTAL NEUTRON SPECTRA  
(ALPHA,N) SPECTRA  
SPONTANEOUS FISSION SPECTRA

## NUCLIDES TO PLOT

(OPTIONAL)



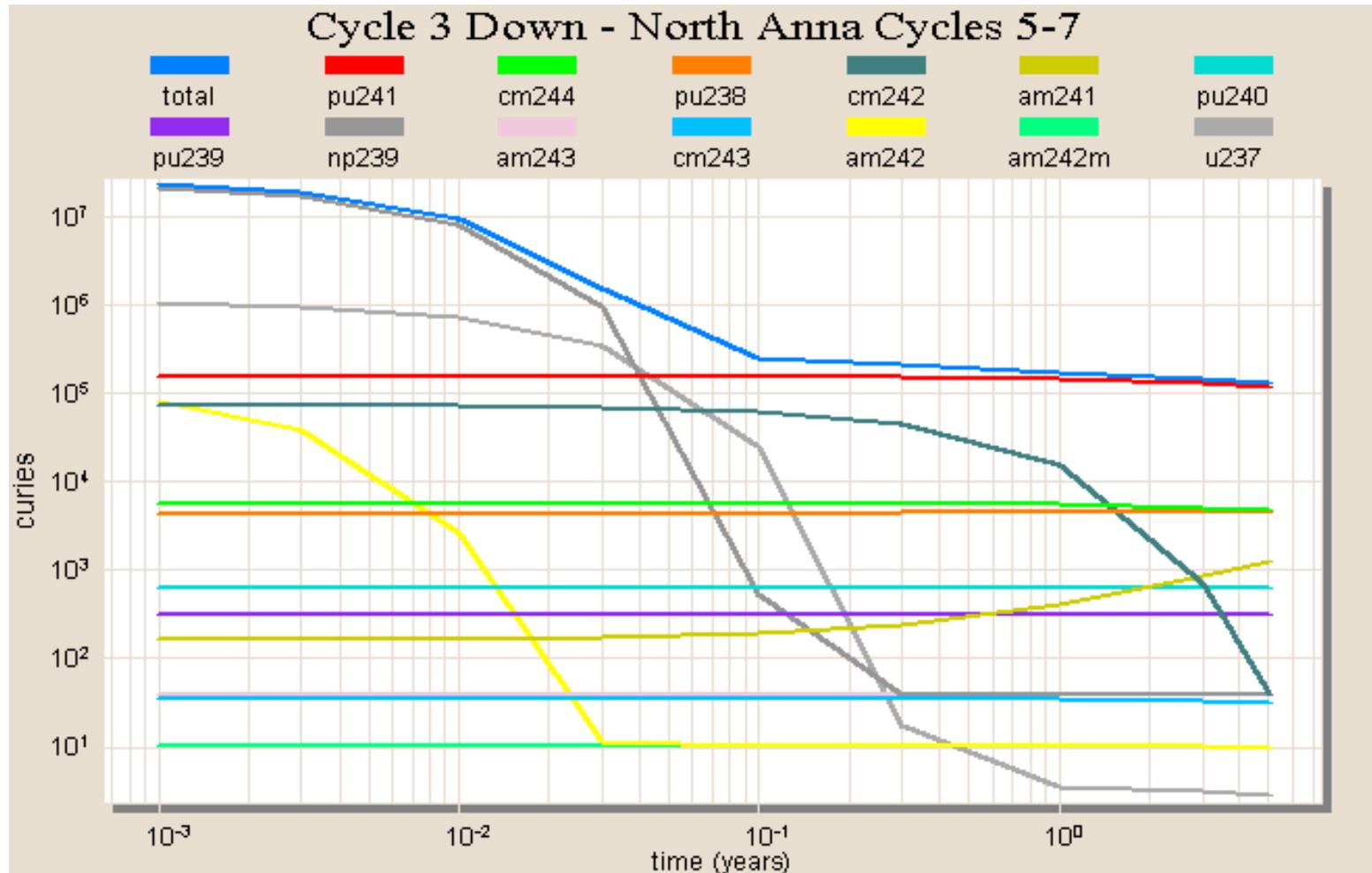
# OPUS Sample Output File

spent fuel at 33 gwd/mthm  
units of concentrations: total power (watts)

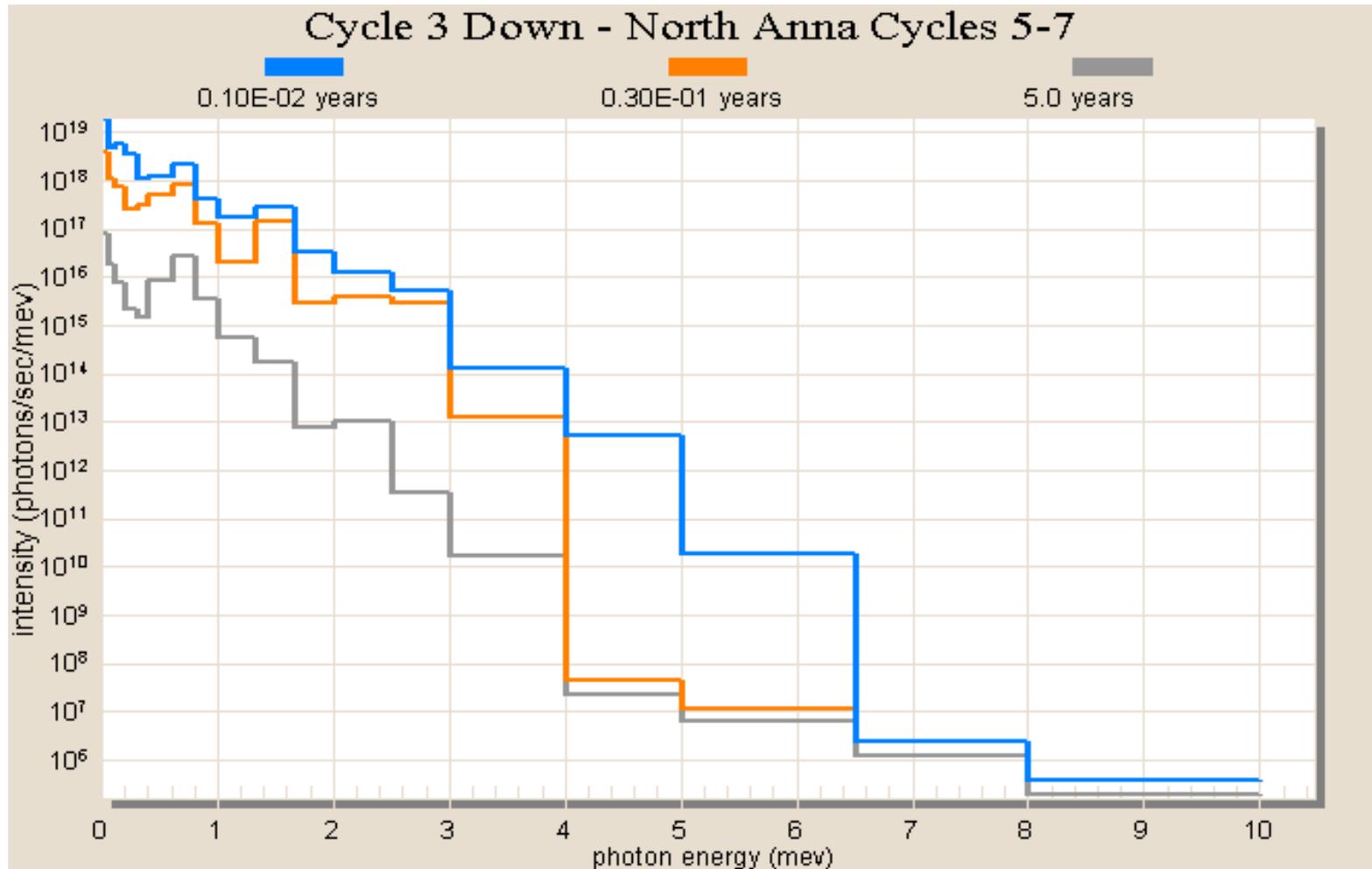
nuclide	time (years)									
	2.738E-02	1.095E-01	2.738E-01	6.571E-01	1.000E+00	2.000E+00	3.000E+00	4.000E+00	5.000E+00	1.000E+01
y90	4.302E+02	4.281E+02	4.262E+02	4.222E+02	4.186E+02	4.085E+02	3.985E+02	3.888E+02	3.794E+02	3.354E+02
ba137m	4.023E+02	4.016E+02	4.001E+02	3.965E+02	3.934E+02	3.844E+02	3.756E+02	3.671E+02	3.587E+02	3.195E+02
cs134	1.479E+03	1.439E+03	1.361E+03	1.197E+03	1.066E+03	7.620E+02	5.445E+02	3.890E+02	2.780E+02	5.176E+01
rh106	5.496E+03	5.197E+03	4.647E+03	3.579E+03	2.833E+03	1.434E+03	7.255E+02	3.671E+02	1.857E+02	6.161E+00
cs137	1.205E+02	1.203E+02	1.198E+02	1.188E+02	1.179E+02	1.152E+02	1.125E+02	1.100E+02	1.074E+02	9.573E+01
pu238	7.652E+01	7.727E+01	7.843E+01	8.014E+01	8.091E+01	8.137E+01	8.097E+01	8.038E+01	7.976E+01	7.668E+01
sr90	8.991E+01	8.973E+01	8.937E+01	8.853E+01	8.778E+01	8.565E+01	8.357E+01	8.153E+01	7.955E+01	7.033E+01
pr144	9.124E+03	8.482E+03	7.330E+03	5.214E+03	3.845E+03	1.581E+03	6.504E+02	2.675E+02	1.100E+02	1.295E+00
cm244	7.735E+01	7.711E+01	7.662E+01	7.551E+01	7.452E+01	7.172E+01	6.903E+01	6.643E+01	6.394E+01	5.279E+01
am241	4.496E+00	5.168E+00	6.505E+00	9.583E+00	1.229E+01	1.991E+01	2.716E+01	3.406E+01	4.062E+01	6.887E+01
eu154	5.428E+01	5.392E+01	5.321E+01	5.159E+01	5.018E+01	4.629E+01	4.271E+01	3.939E+01	3.634E+01	2.428E+01
pml47	6.491E+01	6.475E+01	6.221E+01	5.622E+01	5.135E+01	3.943E+01	3.028E+01	2.325E+01	1.785E+01	4.763E+00
pu240	1.381E+01	1.381E+01	1.381E+01	1.381E+01	1.382E+01	1.382E+01	1.383E+01	1.383E+01	1.384E+01	1.386E+01
pu239	1.028E+01	1.029E+01								
kr85	1.362E+01	1.355E+01	1.341E+01	1.308E+01	1.279E+01	1.199E+01	1.124E+01	1.054E+01	9.878E+00	7.149E+00
sb125	2.577E+01	2.530E+01	2.428E+01	2.203E+01	2.019E+01	1.566E+01	1.215E+01	9.426E+00	7.313E+00	2.055E+00
ce144	8.136E+02	7.563E+02	6.536E+02	4.650E+02	3.429E+02	1.410E+02	5.799E+01	2.385E+01	9.810E+00	1.154E-01
ru106	3.409E+01	3.224E+01	2.882E+01	2.220E+01	1.758E+01	8.893E+00	4.500E+00	2.277E+00	1.152E+00	3.822E-02
cm243	5.165E-01	5.154E-01	5.134E-01	5.086E-01	5.044E-01	4.923E-01	4.804E-01	4.689E-01	4.576E-01	4.052E-01
am242m	3.263E-03	3.262E-03	3.259E-03	3.253E-03	3.248E-03	3.232E-03	3.216E-03	3.200E-03	3.185E-03	3.107E-03
total	8.703E+04	4.531E+04	2.751E+04	1.470E+04	1.036E+04	5.324E+03	3.276E+03	2.296E+03	1.798E+03	1.146E+03
subtotal	1.833E+04	1.729E+04	1.540E+04	1.184E+04	9.450E+03	5.232E+03	3.251E+03	2.285E+03	1.790E+03	1.142E+03

nuclides are listed in descending order of the integral of  $\log(x) dt$  over the time interval 1.000E+00 to 1.000E+01.

# PlotOPUS Actinide Activity Plot



# PlotOPUS Gamma Spectrum Plot



Thank You

# Detail Forms



- Open Compositions Form



- Gamma group structure Form (decay gammas)



- Neutron group structure Form (delayed neutrons)



- ❖ **Open Cases data Form (irradiation or decay data)**



- ❖ **Open Plot Setup Form (generates Plot Table data)**

# Detail Input Form: Compositions

OrigenArp - [Composition Data CZ205.arp]

File Edit View Window Help Express

Options: new, open, save, print, help, run, output, plot, tables, editor, express

Comps: Ok, Apply, Reset, Help, Previous, Next, Enrich, Fuel Dist, Del Row, Cancel

Neutron: Enter composition data (selected), Restart from existing data file

Gamma: Library: bwr7x7

Cases: Moderator Density: 0.4323 g/cc

Summary: Uranium: 1000000 g

Plot Setup: Enrichment (Wt%U235): 2.5

Units: Grams

**Compositions** Irradiation Mode Page 1

	Element	Isotope	Library	Concentration
1	U	234	Actinide	222.5
2	U	235	Actinide	25000
3	U	236	Actinide	115
4	U	238	Actinide	974662.5
5	O	Natural	Natural	50500
6	Cr	Natural	Natural	450
7	Mn	Natural	Natural	29
8	Fe	Natural	Natural	1200
9	Co	Natural	Natural	4.6
10	Zr	Natural	Natural	98200
11	Gd	Natural	Natural	544
12	Ni	Natural	Natural	450
13	Sn	Natural	Natural	11600
14				

Ready NUM

# Detail Input: Neutron Groups

The screenshot shows the OrigenArp software interface for Neutron Energy Spectra. The window title is "OrigenArp - [ Neutron Energy Spectra CZ205.arp]". The menu bar includes File, Edit, View, Window, Help, and Express. The toolbar contains icons for new, open, save, print, help, run, output, plot, tables, editor, and express. The left sidebar has buttons for Options, Comps, Neutron, Gamma, Cases, Summary, and Plot Setup. The main area shows "Group Structure" set to "47GpBUGLE" and "Number of Groups" set to "47". The "Neutron Energy" section displays a table of 47 energy values in scientific notation.

1	1.9640300e+007	2	1.4190700e+007	3	1.2214000e+007	4	1.0000000e+007	5	8.6070800e+006
6	7.4081800e+006	7	6.0653100e+006	8	4.9658500e+006	9	3.6787900e+006	10	3.0119400e+006
11	2.7253200e+006	12	2.4659700e+006	13	2.3652500e+006	14	2.3457000e+006	15	2.2313000e+006
16	1.9205000e+006	17	1.6529900e+006	18	1.3533500e+006	19	1.0025900e+006	20	8.2085000e+005
21	7.4273600e+005	22	6.0810100e+005	23	4.9787100e+005	24	3.6883200e+005	25	2.9721100e+005
26	1.8315600e+005	27	1.1109000e+005	28	6.7379370e+004	29	4.0867700e+004	30	3.1827800e+004
31	2.6058400e+004	32	2.4175500e+004	33	2.1874900e+004	34	1.5034400e+004	35	7.1017380e+003
36	3.3546300e+003	37	1.5846100e+003	38	4.5399900e+002	39	2.1445400e+002	40	1.0130100e+002
41	3.7266490e+001	42	1.0677000e+001	43	5.0434800e+000	44	1.8553900e+000	45	8.7642500e-001
46	4.1399400e-001	47	1.0000100e-001	48	1.0000100e-005				

# Detail Input: Irradiation Case Data

The screenshot shows the OrigenArp software interface for setting up an irradiation case. The window title is "OrigenArp - [Irradiation Case 1 CZ205.arp]". The interface includes a menu bar (File, Edit, View, Window, Help, Express) and a toolbar with various icons for file operations and simulation control. The main workspace is divided into several sections:

- Title:** Case 1
- Basis:** 1 MTU
- Start ALL Irradiation Cases at Time Zero:**
- Beginning Time:** 0.0
- Time Units:** Days
- Summary Table:**

Power(MW/BASIS)	Cumulative Time	Save Results
8.393	80.7	<input type="checkbox"/>
8.393	161.4	<input type="checkbox"/>
8.393	242.1	<input type="checkbox"/>
8.393	322.8	<input type="checkbox"/>
8.393	403.5	<input type="checkbox"/>
8.393	484.2	<input type="checkbox"/>
8.393	564.9	<input type="checkbox"/>
8.393	645.6	<input type="checkbox"/>
8.393	726.3	<input type="checkbox"/>
8.393	807	<input type="checkbox"/>

At the bottom of the window, there is a status bar with the text "Open an existing document" and a "NUM" indicator.

# Detail Input: Decay Case Data

OrigenArp - [Decay Case 12 CZ205.arp]

File Edit View Window Help Express

Options new open save print help run output plot tables editor express

Comps Ok Apply Reset Help Previous Next Cancel Fill Insert Delete Options Element

Neutron Title Case 12 Decay Case # 12

Gamma Basis 1 MTU

Beginning Time = 0.000000e+000 Time Units Days (Alpha,n) U02

(Alpha,n) Cutoff 1e-005

Alpha Groups 200

Bremsstrahlung U02

Gamma Library Total

Print Neutron Source Calculation Details

Cases

Time at which output is desired		
Cumulative Time	Source Spectra	Save Results
1	<input type="checkbox"/>	<input checked="" type="checkbox"/>
3	<input type="checkbox"/>	<input checked="" type="checkbox"/>
10	<input type="checkbox"/>	<input checked="" type="checkbox"/>
30	<input type="checkbox"/>	<input checked="" type="checkbox"/>
100	<input type="checkbox"/>	<input checked="" type="checkbox"/>
300	<input type="checkbox"/>	<input checked="" type="checkbox"/>
1000	<input type="checkbox"/>	<input checked="" type="checkbox"/>
1294	<input type="checkbox"/>	<input checked="" type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>

Ready NUM