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Title: Fission Product -ray Measurements of 235U and MCNP6 Predictions

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Fission Product γ-ray Measurements of ^{235}U and MCNP6 Predictions

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LA-UR-###

Delayed Neutron & Gamma Counting at RMCC

- DNC system was designed and built in 2010 for the analysis of DN emissions from ^{233}U, ^{235}U & ^{239}Pu.
- Upgraded in 2012 to accommodate measurement of gammas from SNM.
- This system analyzes the temporal behaviour of the delayed neutrons and gammas to discern which fissile isotope(s) is(are) present
- Complements existing nuclear analytical instrumentation at RMCC

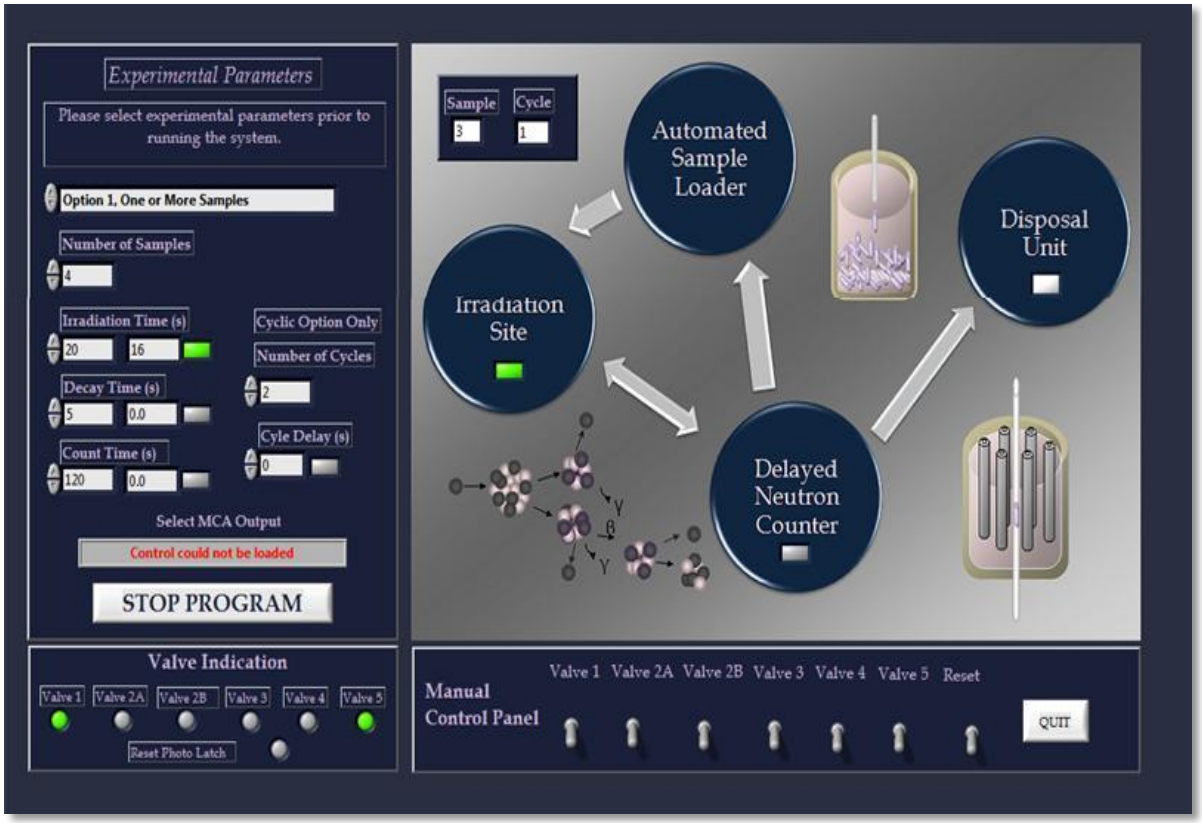
Delayed gamma measurements from the fission of nat. U were compared to MCNP6 simulations.

Delayed Neutron & Gamma Counting System

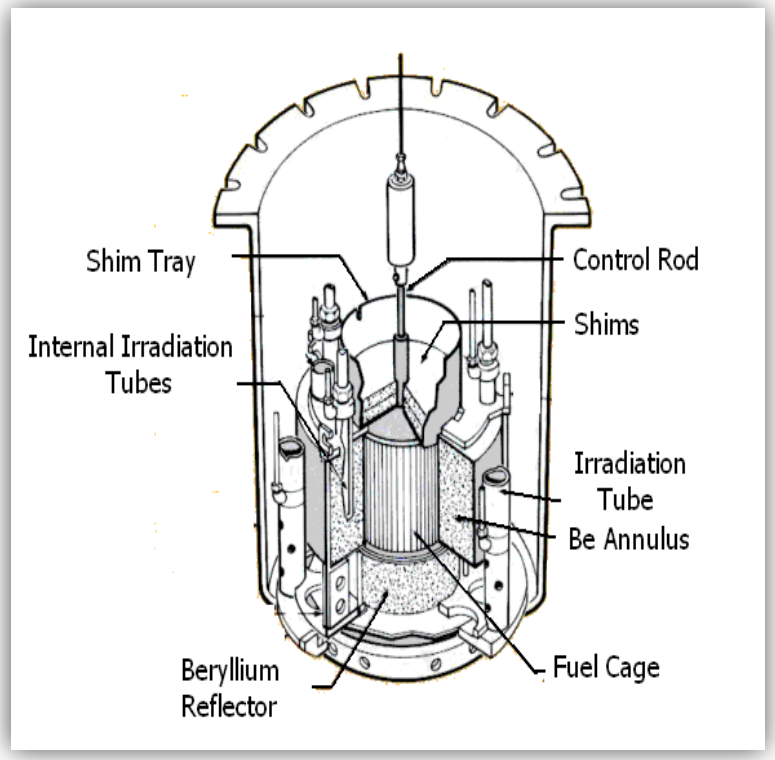
Aqueous samples containing fissile content is prepared from certified reference materials

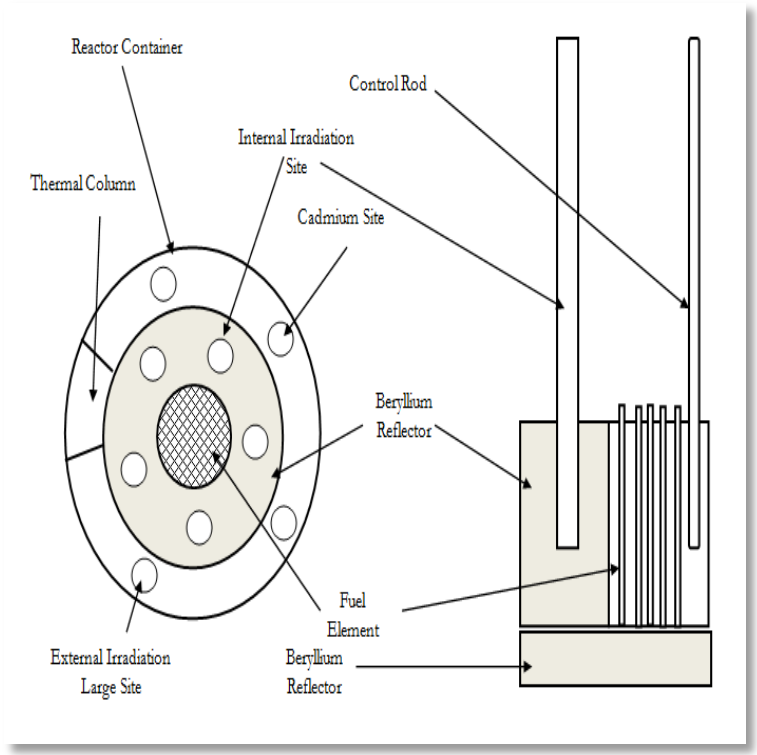
LabVIEW software controls data acquisition and hardware components.

User specifies: Irradiation, decay, count time, count intervals and # of samples.



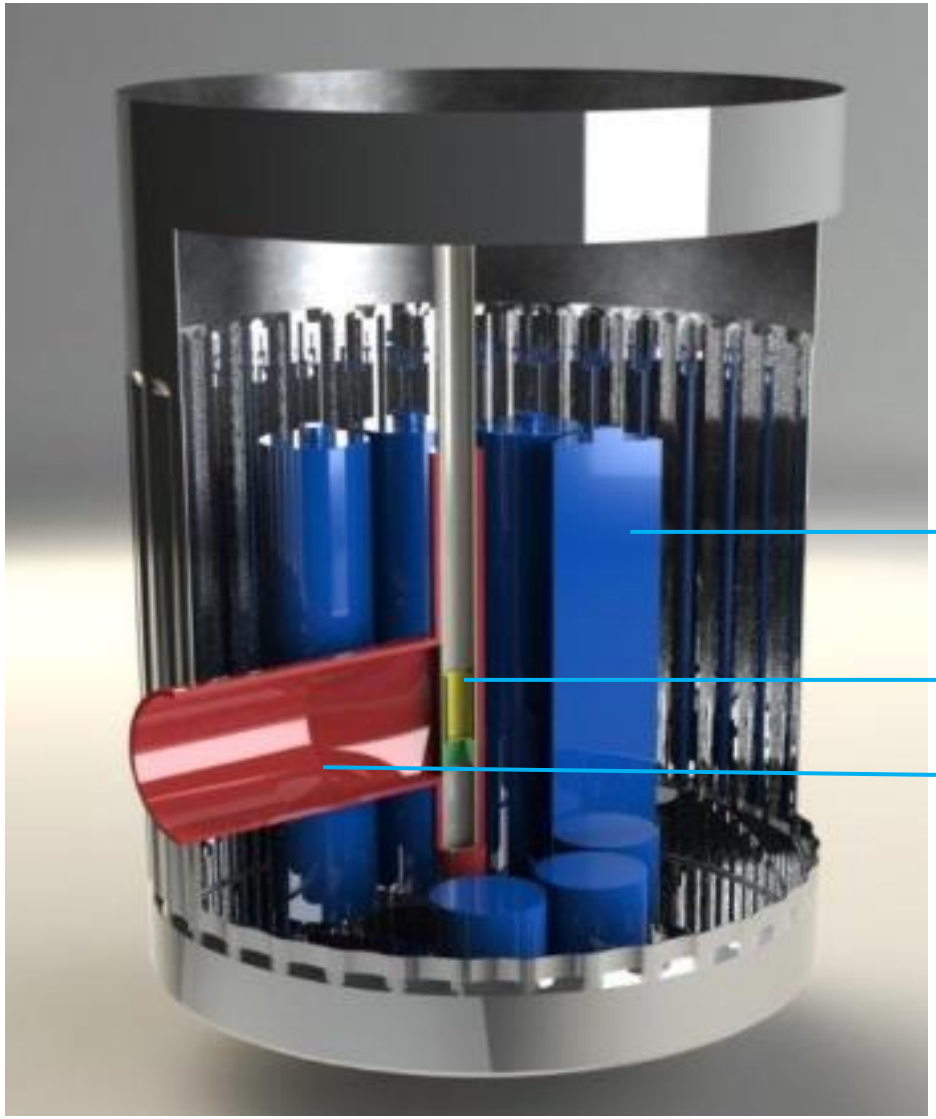
Irradiation in the SLOWPOKE-2 Reactor





20 kW research reactor enriched to 19.89 % ^{235}U

The Delayed Neutron & Gamma Counter



Paraffin moderator not shown.

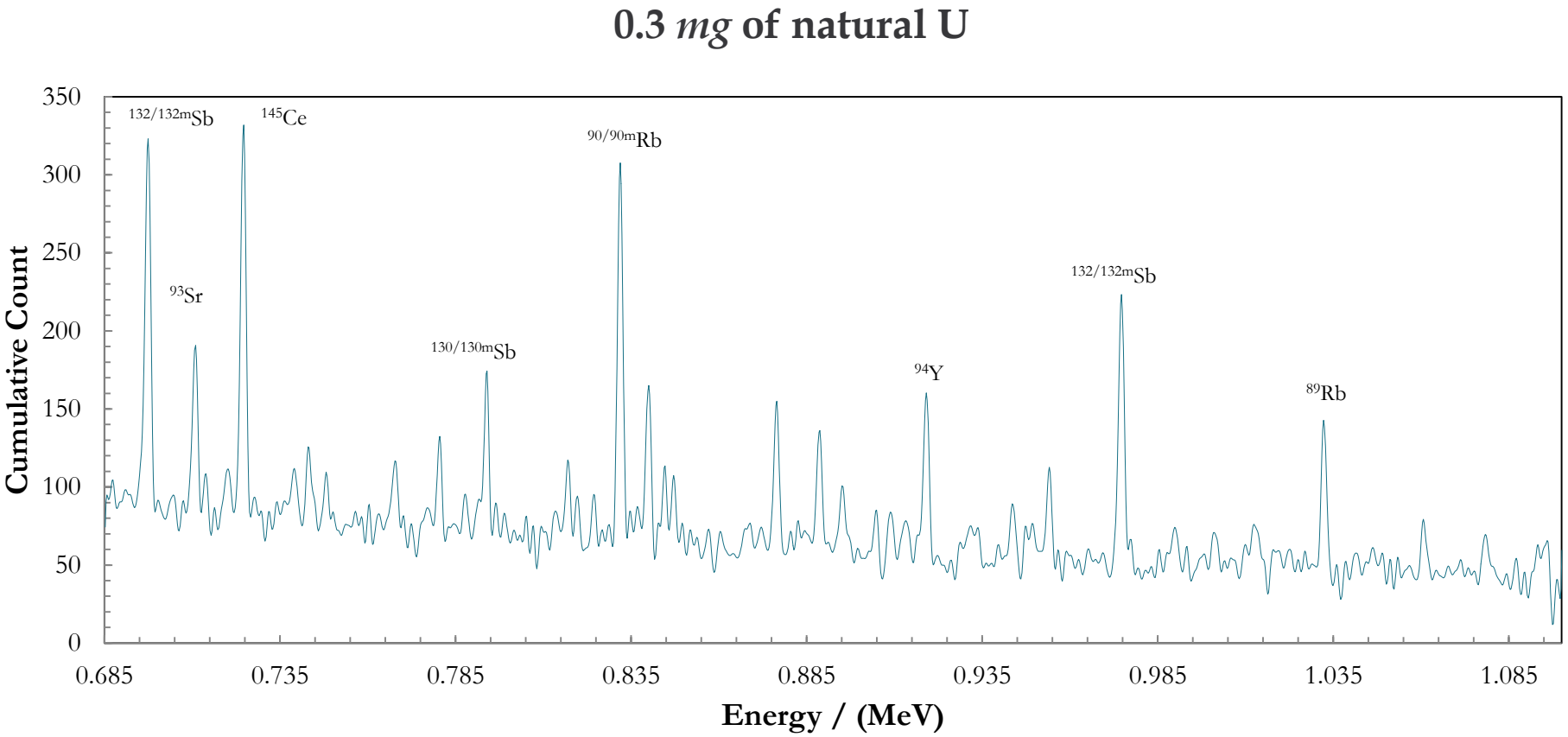
Fissile Analysis: An Example

- Imports count files for neutrons and gammas:

SLOWPOKE Test Data					
11/04/2013	11:47 AM				
Standard? YES					
Sample #	**Cycle #**	**Time**	**Energy Bin 1**	**…**	**Energy Bin N**
1	1	30	100		50
		60	150		250
		…	…		…
		600	200		4000

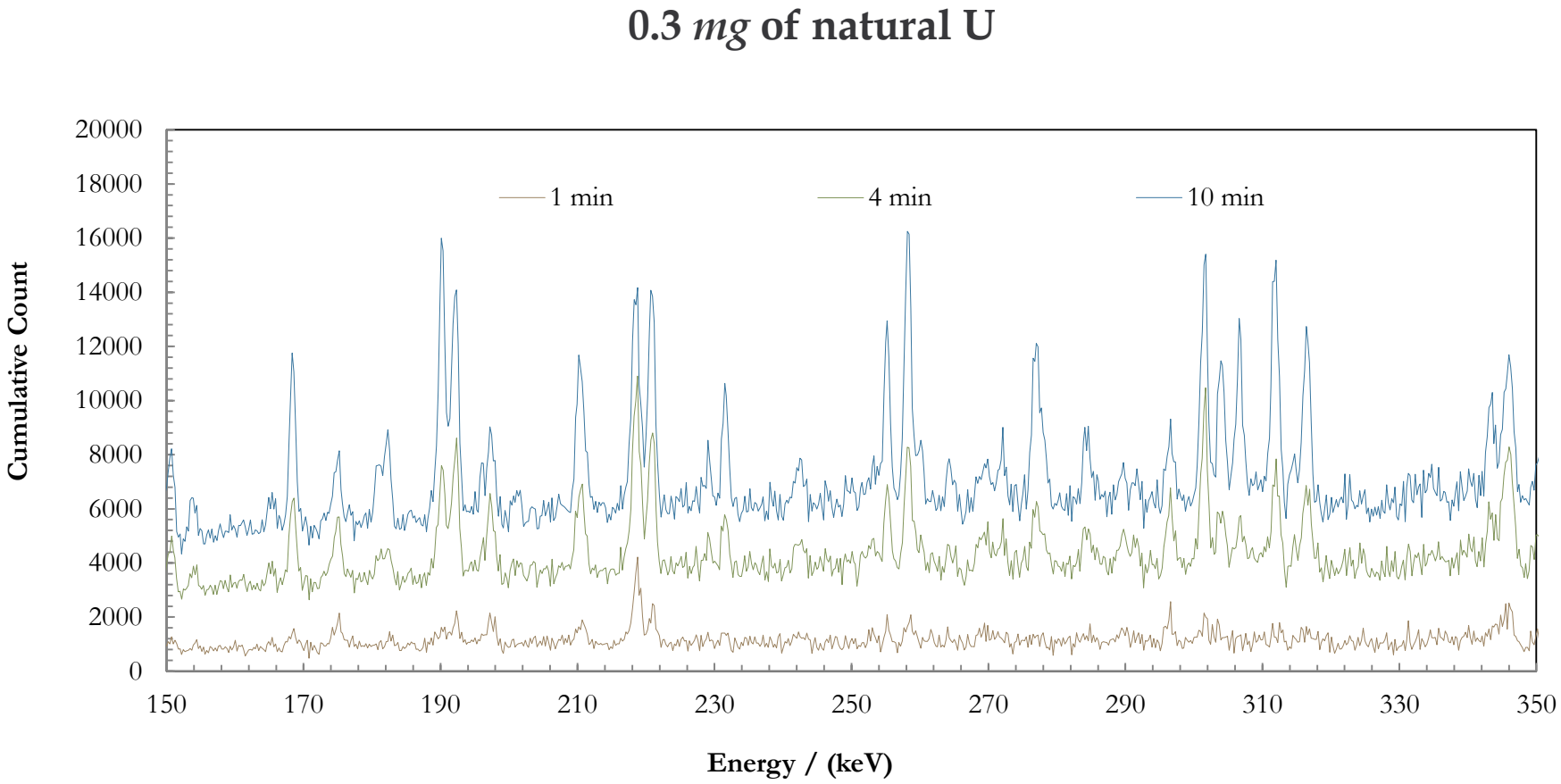
- Matlab script corrects for background, dead time, normalizes to counts per second

Fissile Analysis: An Example



- 60 *s* irradiation, 30 *s* decay, 570 *s* count.
- Background subtracted, corrected for dead time effects.

Fissile Analysis: An Example



- 60 *s* irradiation, 30 *s* decay, 570 *s* count.
- Background subtracted, corrected for dead time effects.

Delayed Gamma Preliminary Measurements

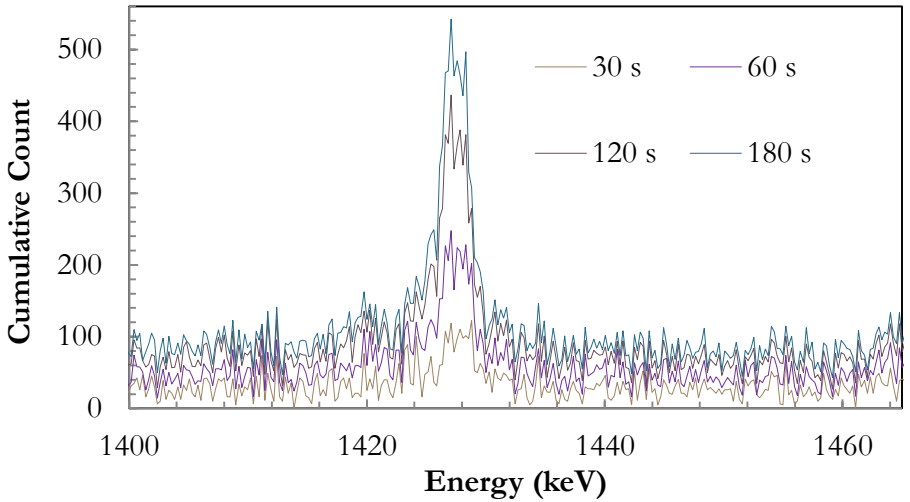
Measurements were collected and the following examples were analyzed:

A. ^{235}U Short Count

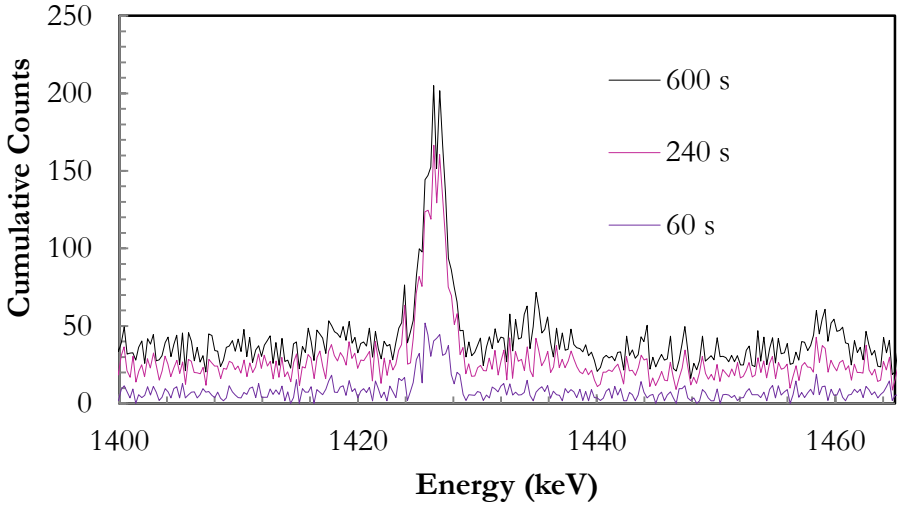
- Nat. U. in aqueous solution
- $t_{irr} - t_{decay} - t_{count}$ = 60 s – 8 s – 180 s
- Count times analyzed:
  30 s, 60 s, 120 s, 180 s

B. ^{235}U Medium Count

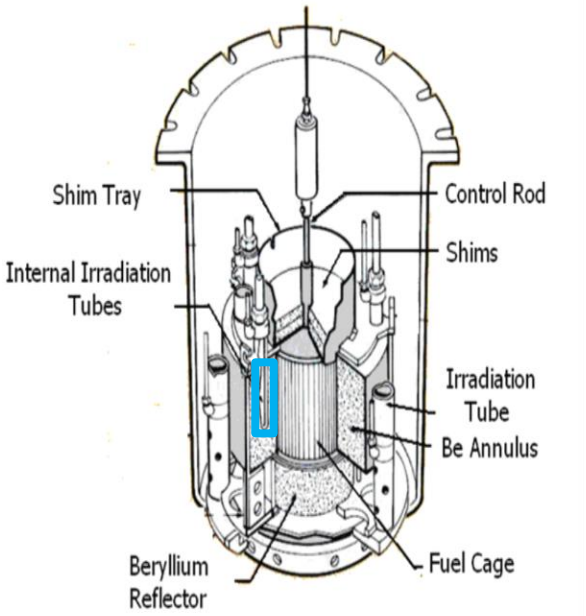
- Nat. U. in aqueous solution
- $t_{irr} - t_{decay} - t_{count}$ = 60 s – 30 s – 600 s
- Count times analyzed:
  60 s, 240 s, 600 s



Sr-94 Peak (1427 keV, $t_{1/2}$ = 1.25 min)



MCNP6 Model - Geometry



Irradiation:

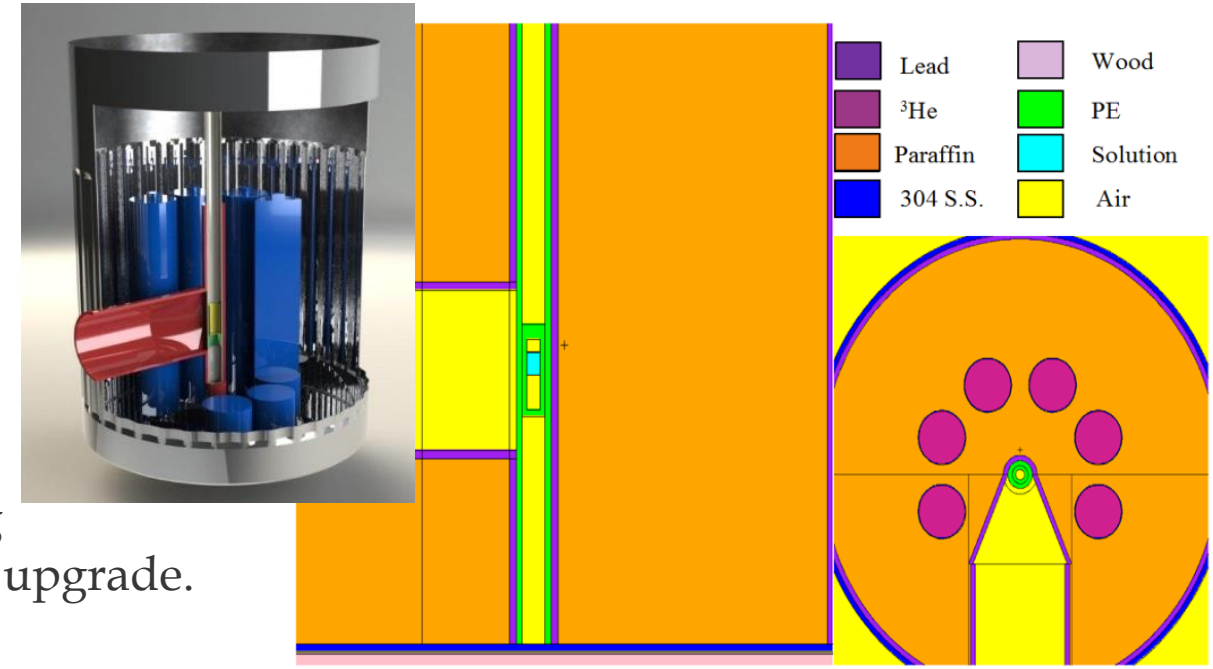
SLOWPOKE-2 model provided by AECL

Vial placed inside irradiation site to determine neutron flux energy distribution.

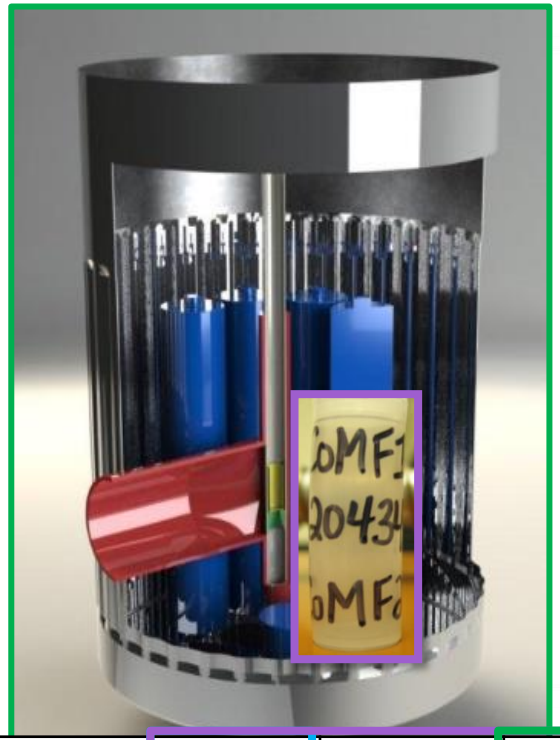
Detection:

HPGe crystal modeled to manufacturer's specifications.

DNGC system modeled using dimensions measured during upgrade.



MCNP6 Model - Source & Tallies



Energy	60 s	90 s	660s
0.01 MeV	t_{irr}	t_{decay}	t_{count}
…			
1.99 MeV			
2.00 MeV			

Irradiation of Fissile Content

- Reproduces neutron flux distribution in SLOWPOKE-2 reactor.

DG Production

- DG=lines, sample DGs using models based on line emission data augmented by 25-group data.
- Surface current tally with time bins corresponding to experiments recorded emission energies and times.

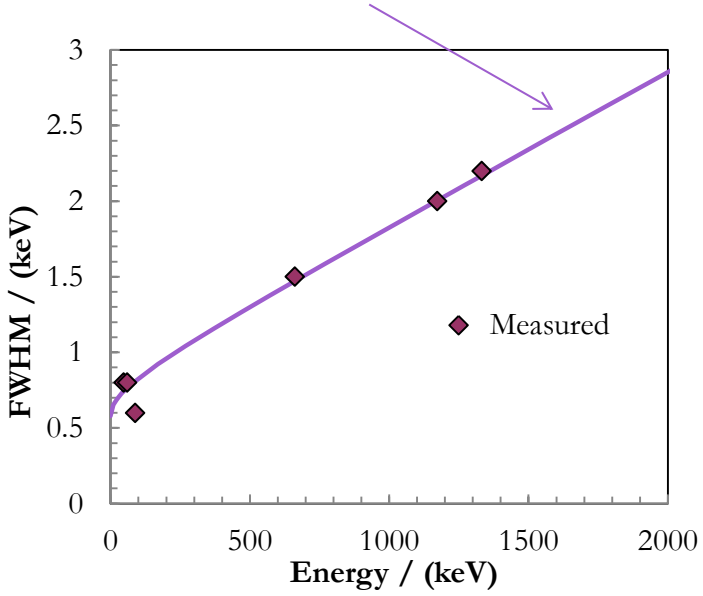
Detection

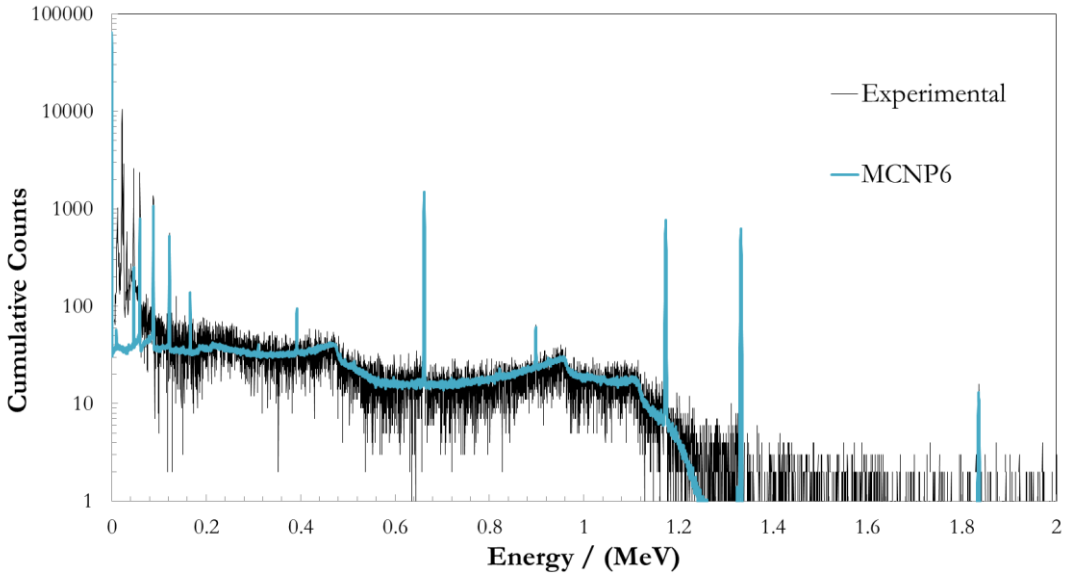
- Pulse height tally records energy depositions within HPGe crystal.

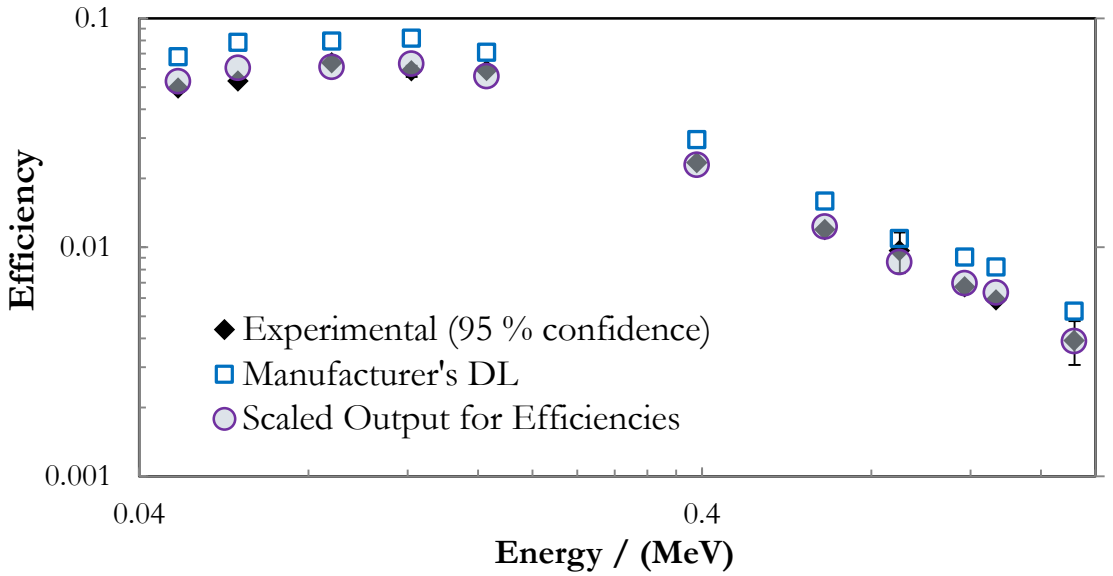
Multinuclide HPGe Detector Response in MCNP6

- Comparisons of MCNP & exp. FWHM and efficiencies were performed.
- *Gaussian Energy Broadening* (GEB) card used to reproduce energy resolutions.

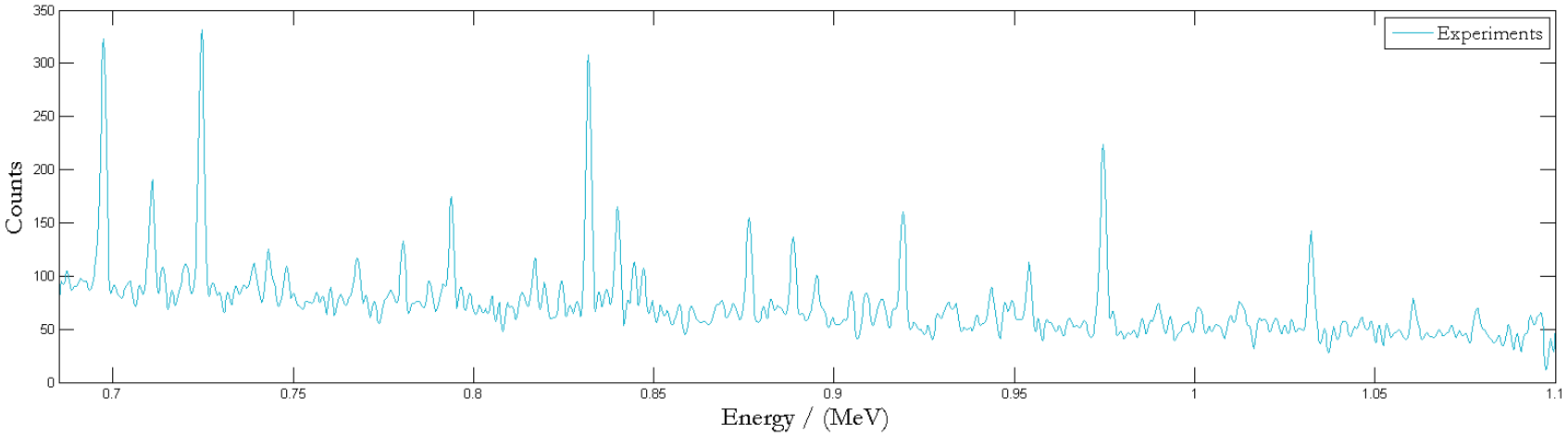
$$FWHM = a + b\sqrt{E + cE^2}$$





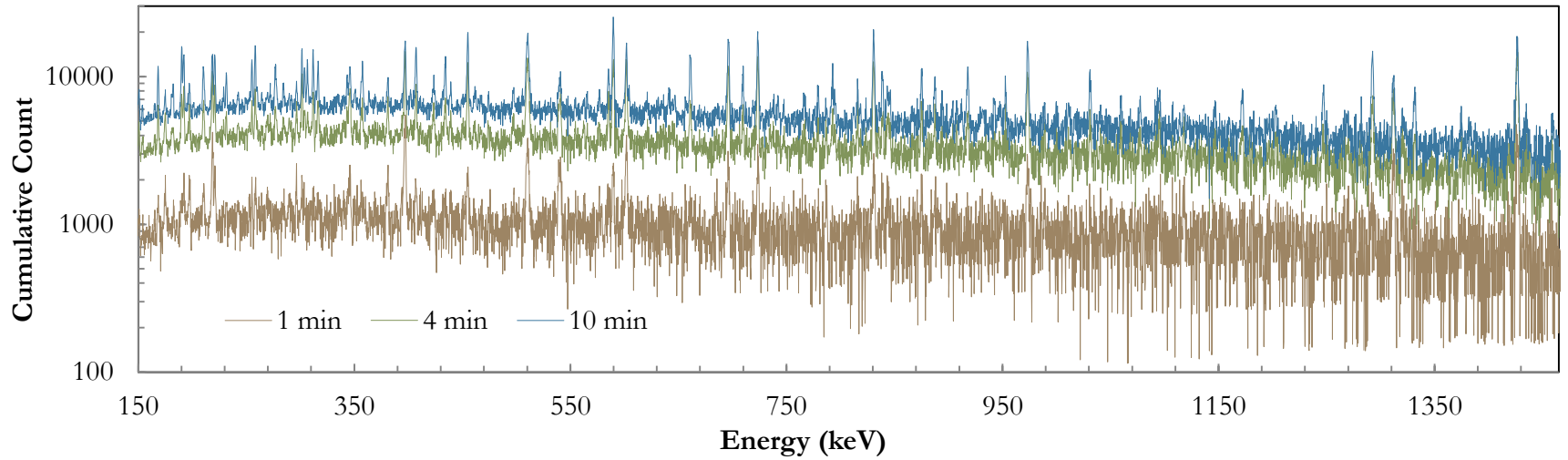


Fission Product γ-ray Spectra

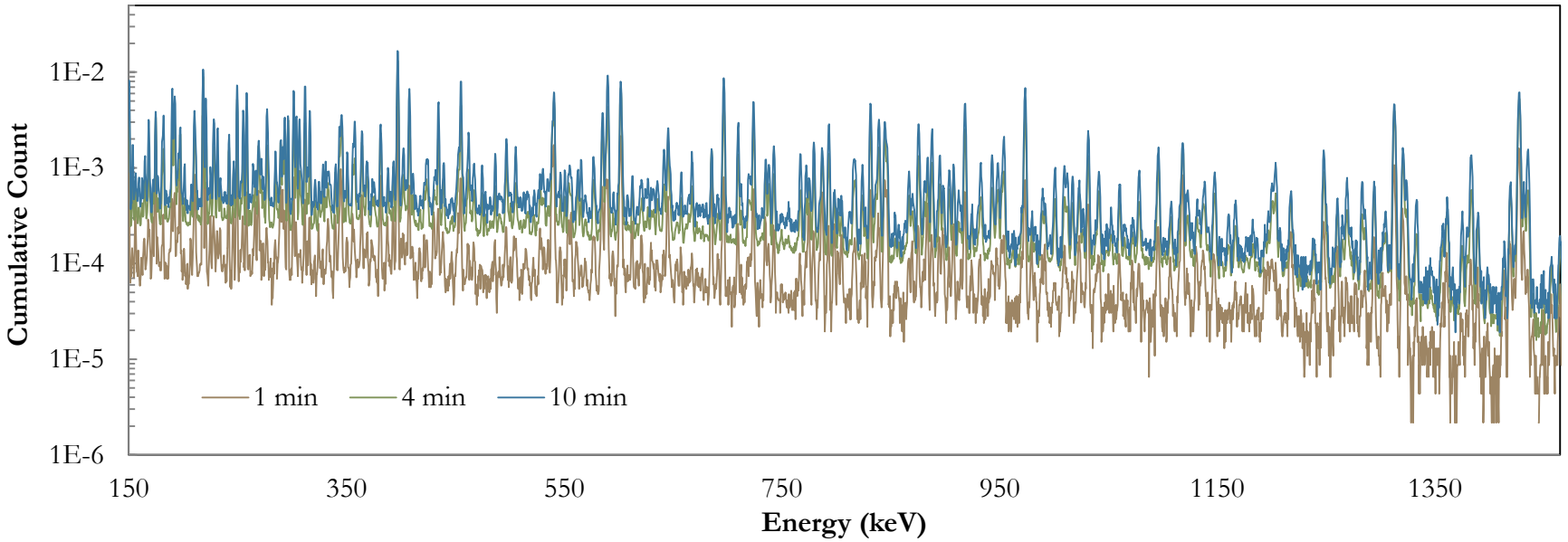


Delayed Gamma Modeling: Measurement Sets and their corresponding MCNP6 outputs

EXPERIMENT



MCNP6



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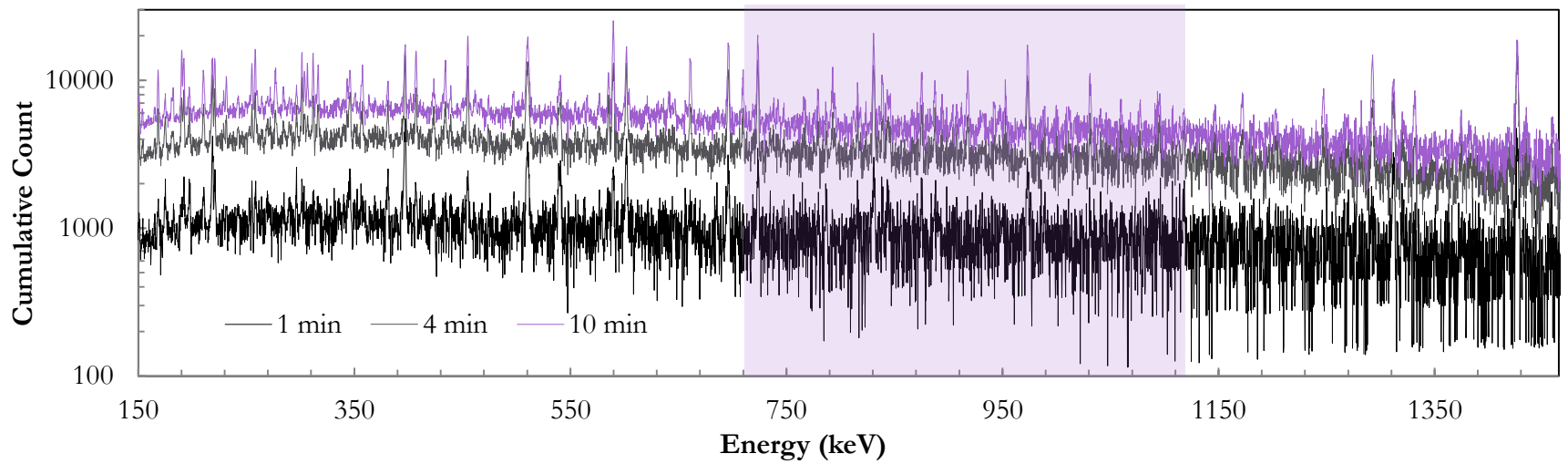
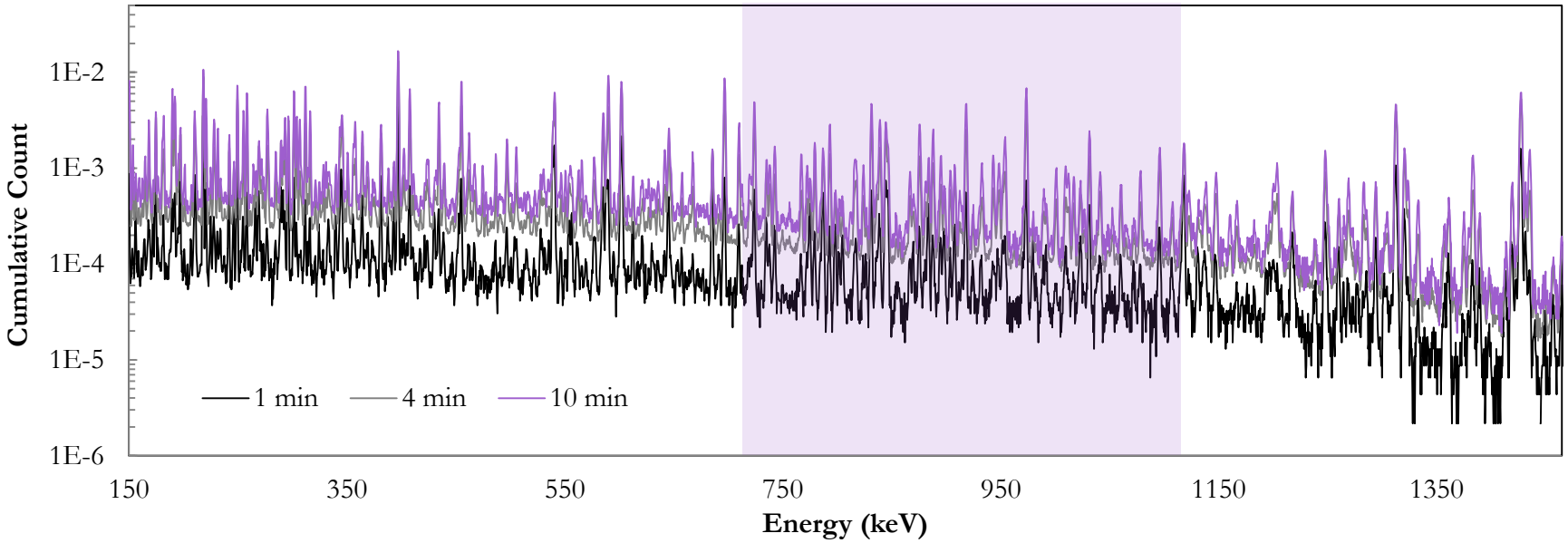
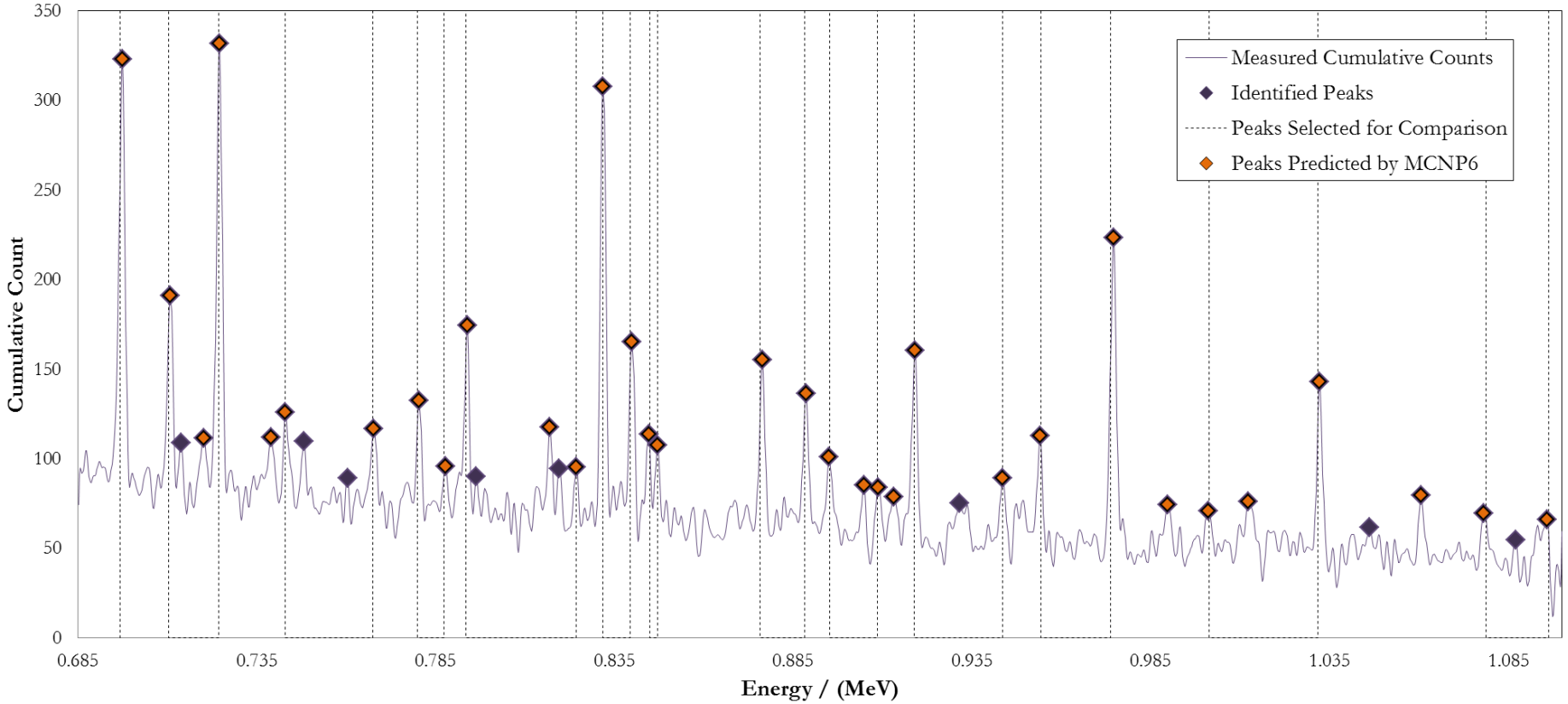


MCNP6



Fission Product γ-ray Spectra



- From 0.1 – 1.45 **176** Measured Peaks 130 Predicted by MCNP
- 25 selected for comparison in 0.685 – 1.1 *MeV* range

Fission Product γ-ray Relative Intensities

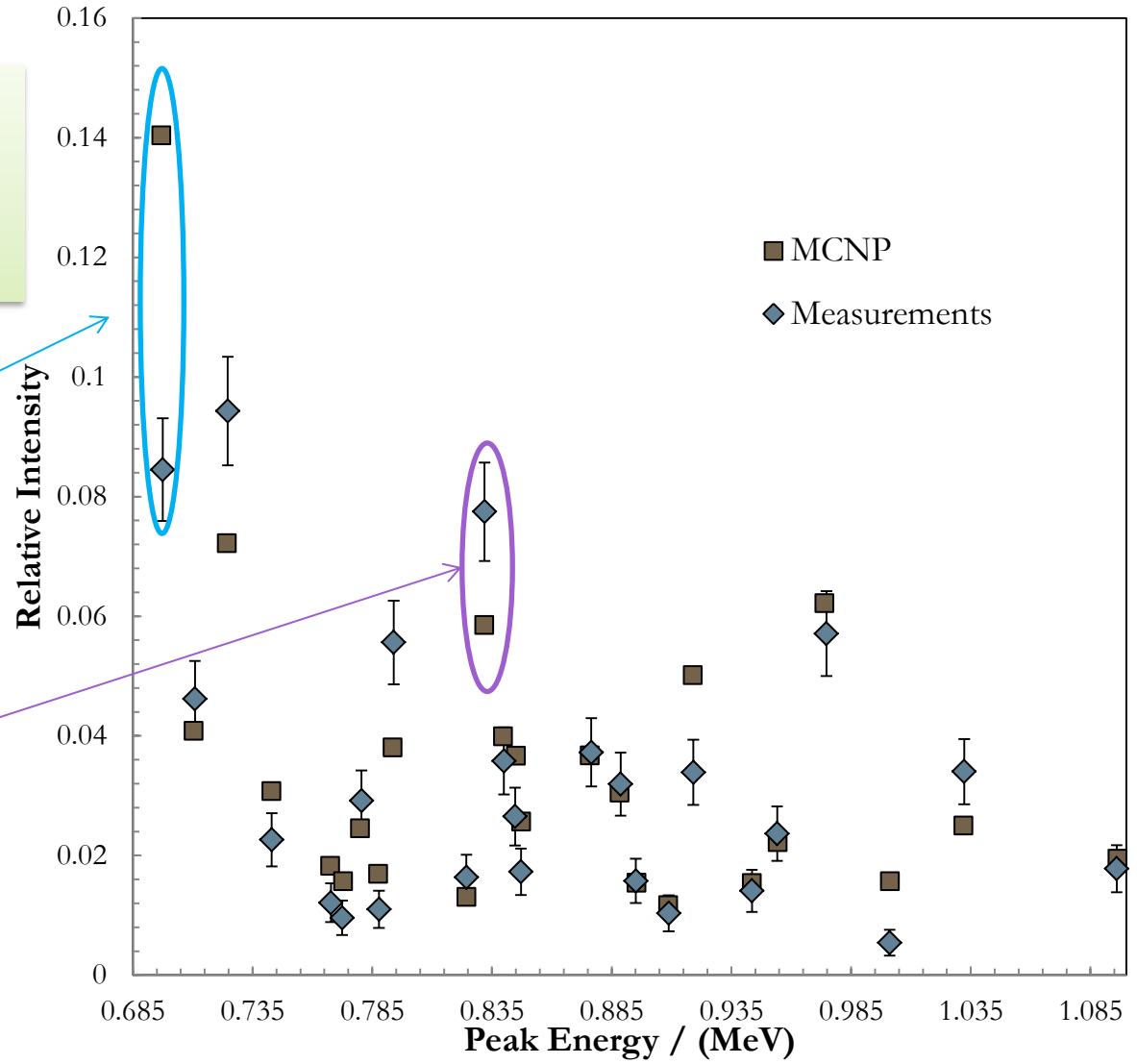
DG emission-spectra consist of two structures: multigroup and line data. All data are based on the ENDF/B-VI evaluation.
- (*Durkee et al. Nucl. Tech. 180 (2012)*)

^{132}Sb 0.697 MeV
ENDFVI: 4.2 min 100 %
ENDFVII.1: 2.8 min 86 %

^{132m}Sb 0.697 MeV
ENDFVI: 2.8 min 86 %
ENDFVII.1: 4.1 min 100%

^{90}Rb 0.832 MeV
ENDFVI: 28 %
ENDFVII: 40 %

^{90m}Rb 0.832 MeV
ENDFVI: 97 %
ENDFVII:94 %



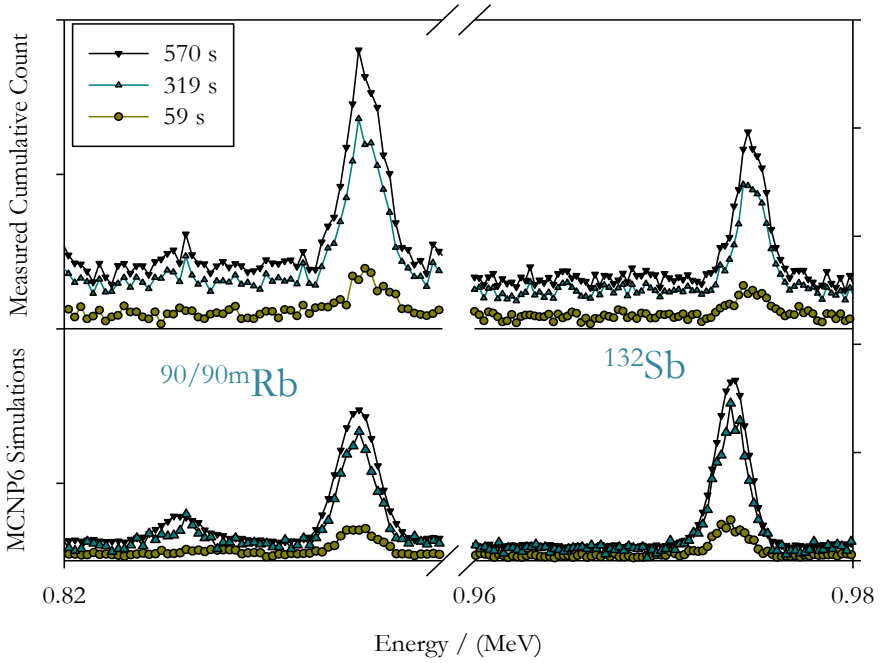
Future Work & Conclusions

Conclusions

- Preliminary comparisons of measured γ ray spectra of ^{235}U fission and MCNP6.1 are underway.
- MCNP predicted the presence of the majority of prominent measured peaks.
- Relative intensities of 25 most prominent peaks were in general agreement with several notable discrepancies, namely $^{90/90m}Rb$ and $^{132/132m}Sb$ peak energies.

Future Work

- MCNP6 comparisons with ^{239}Pu, ^{233}U underway
- Comparison of peak growth with respect to count time will also be included in future efforts.
- Will examine effects of updating cindergl.dat and cinder.dat with ENDFVII data for individual isotopes.



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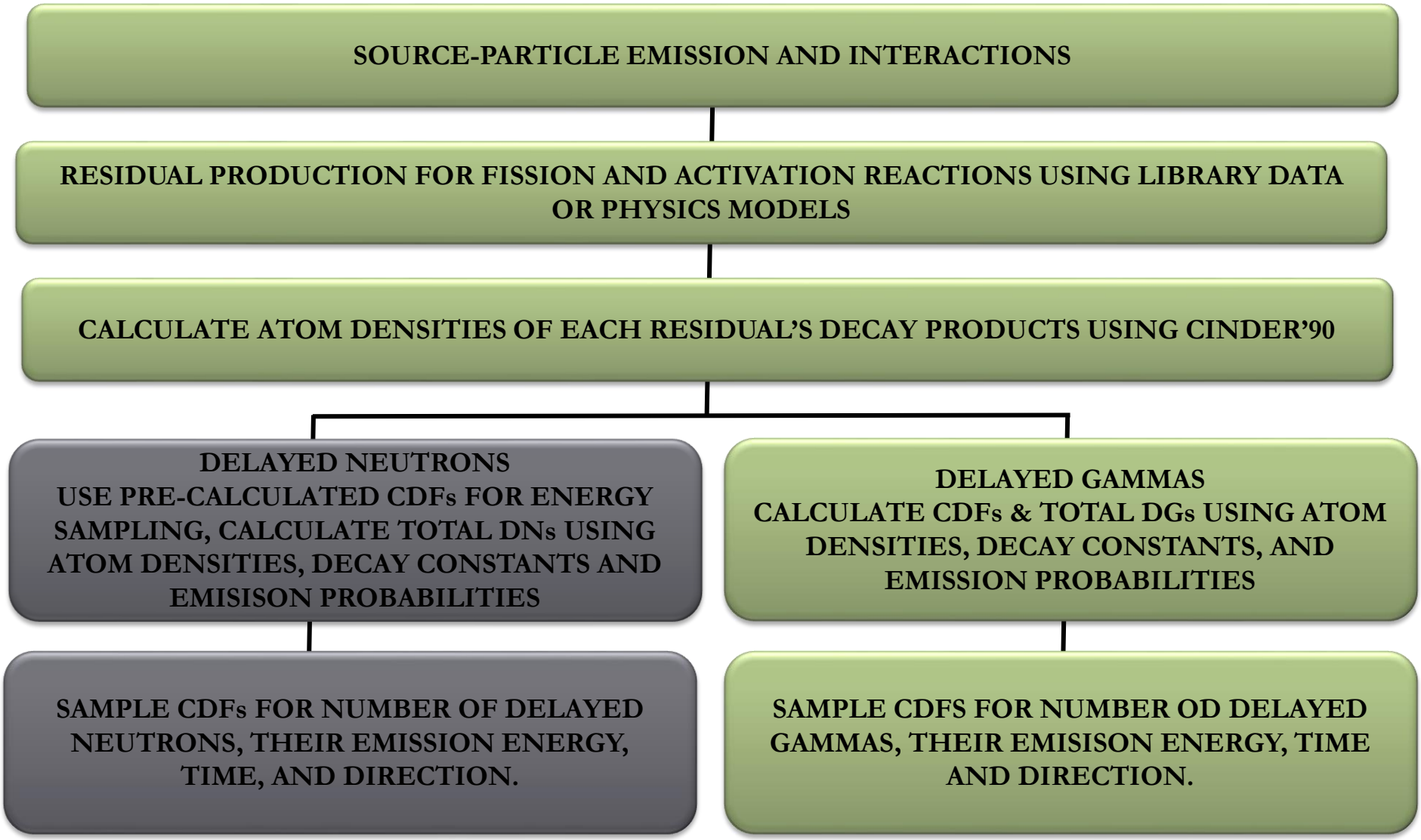
C. McEwen and J. Shaw, Royal Military College of Canada

DG Production Procedure using Physics-Model Technique (Durkee et al. *Nucl. Tech.* 180 (2012) 336)



Relative Contributions from DU, Nat U, empty vials and HNO_3 solution