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Fast Neutron Shielding

Paul Asare Agyapong [SARA with Dr. Jonathan Dowell]

PADGS

NEN3

INFO MGMT & MODELING SIM

BACKGROUND

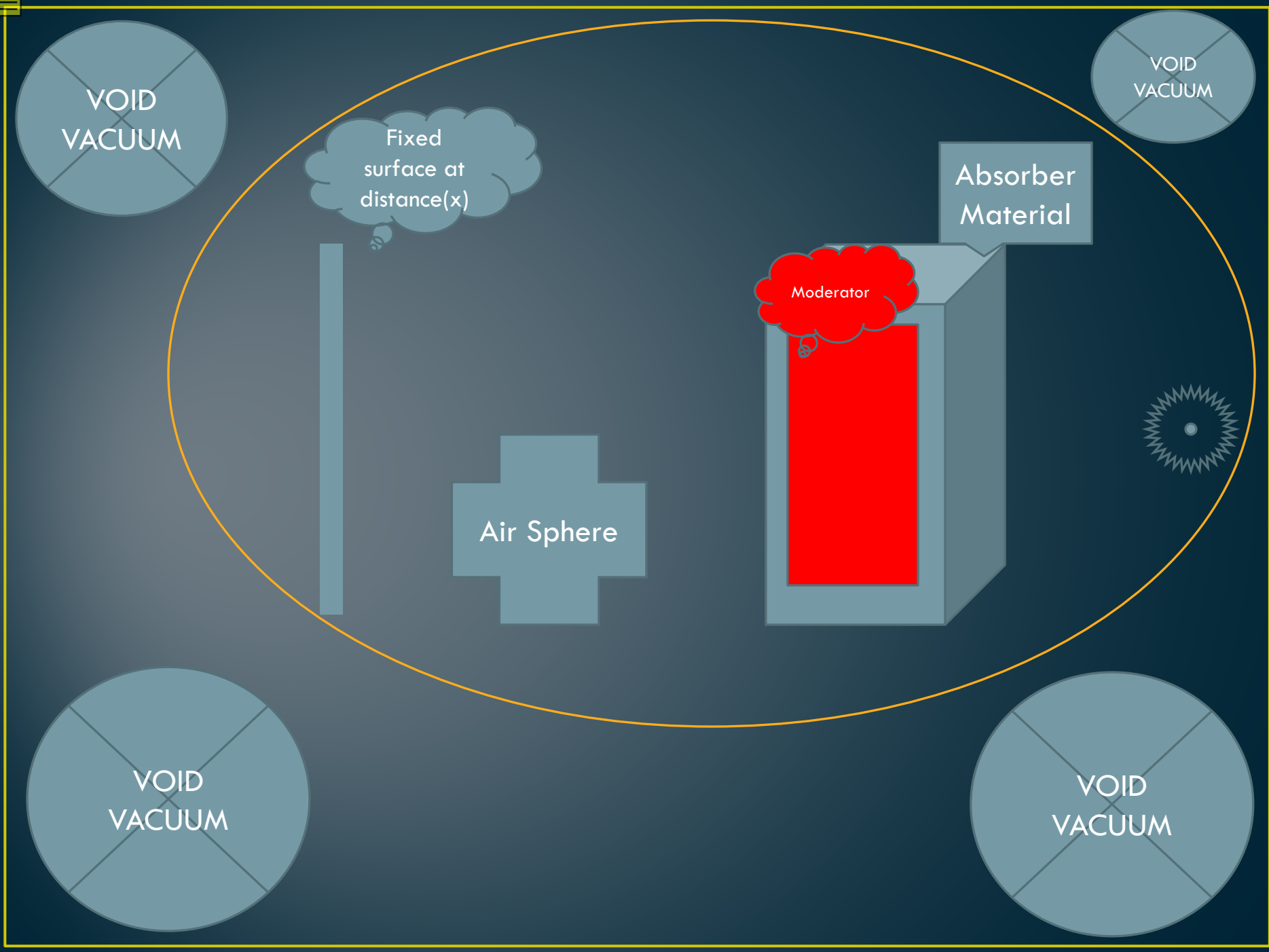
- In Neutron shielding, neutron energy is the primary determinant of shield characteristics(4)
- Fast Neutrons ($E \geq 1 \text{ MeV}$) must first be thermalized with high neutron scattering materials(1)
- These thermal neutrons can then be absorbed or shielded with high cross sections for neutron absorption
- Rain-gauges, which utilize principles of nucleic detection, operate with thermal neutron detectors
- Systems such as He-3 detectors measure rain by correlating neutron moderation with rain level(6)
- From this relationship it's possible to determine unknown levels of substance with a known detector signal strength

CONCEPTS

- Multiple sources with desired radiation detection
- Need to optimize design of material which prevents source interference
- Multilayered design required for fast neutron shielding
- Utilize Monte Carlo N Particle program to determine shielding efficiencies of materials and Geometries(2)
- Sandwiched combination of strong neutron absorber with effective moderators
- Optimum results achieved with greatest flux reduction ratio at fixed distance from neutron source

SCOPE

- MCNP6 software
- Material properties for Boron Carbide, Cadmium, Gadolinium, Polyethylene, Graphite, and Light Water.
- 200,000,000 particles per each simulation
- Varying geometries on increasing logarithmic scale
- Moderator thicknesses of (1, 2, 5, 10, 20, 50) mm
- Absorber thicknesses of (1, 2, 5, 10, 20) mm on each side
- Isotropic fast neutron emitter- Watt's distribution (PU-239) (3)
- Air modeled as N3O



```

Test Run
c cell cards
c # mat# dens          sur desc          data
  1      3  -.00123      -1  2      imp:n=1  $shield
c  2      2 -19.86       -3          imp:n=1  $Plutonium sphere
  3      3  -.00123      -2          imp:n=1  $inner filling
  4      3  -.00123      -4          imp:n=1  $back sensor
  5      3  -.00123      1  4  -5      imp:n=1  $airshell
  6      0              5          imp:n=0  $outside
c end of cell cards for sample problem

c surface cards
c # type          data
  1 RPP           -19 -10 -20 20 -20 20      $shield
  2 RPP           -17 -12 -20 20 -20 20      $moderator
c  3 so 4.5       $plutonium ball
  4 RPP           -21 -20 -20 20 -20 20      $back sensor
  5 so 50         $airshell

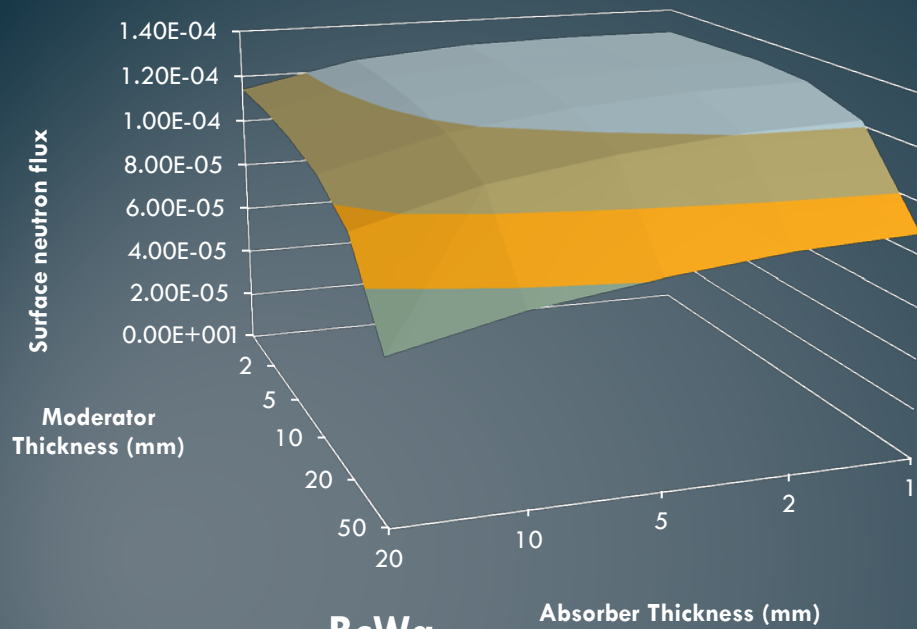
c data cards
c material cards
M1  5010  4  6012  1      $boron carbide(-2.52)
M8  64157  1      $Gadolinium(-7.9)
M6  48112  1      $cadmium(-8.65)
M2  94239  1      $PU-239(-19.86)
M3  7014   3  8016  1      $N3O-air(-.00123)
M4  6012   1      $graphite(-2.09)
M5  1001   2  8016  1      $light water(-1)
M7  6012   1  1001  2      $CH2 Polyethylene(-.93)
c source specification
SDEF POS=0.1 0 0 ERG=d1 WGT=1 TME=0 PAR=N
SP1  -3 .966 2.842
c tally specification
f2:n 1.1 $surface flux through shield inlet
SD2 1600
E2 1 12i 14
c
f22:n 1.2 $surface flux through shield exit
SD22 1600
E22 1 12i 14
c
f32:n 4.1 $surface flux through back sensor
SD32 1600
E32 1 12i 14
NPS          1000000

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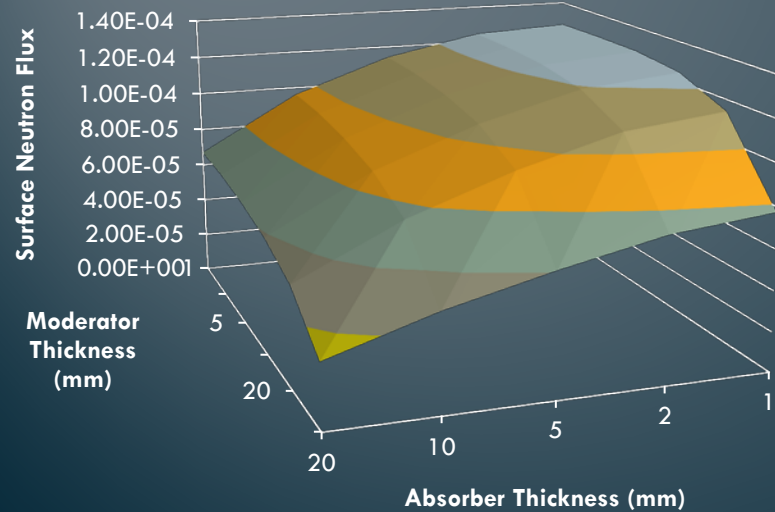
RESULTS

mm	mm		1 MEV	2 MEV	3 MEV	4 MEV	5 MEV	6 MEV	7 MEV	8 MEV	9 MEV	10 MEV	11 MEV	12 MEV	13 MEV	14 MEV	TOTAL
	0	0 an_out	3.62E-05	3.69E-05	2.45E-05	1.43E-05	7.76E-06	4.03E-06	2.03E-06	9.92E-07	4.72E-07	2.24E-07	1.04E-07	4.75E-08	2.11E-08	9.53E-09	1.27E-04
	1	1 BcPe0101_out	3.86E-05	3.64E-05	2.36E-05	1.37E-05	7.48E-06	3.89E-06	1.94E-06	9.51E-07	4.53E-07	2.15E-07	9.95E-08	4.55E-08	2.04E-08	9.21E-09	1.27E-04
	1	2 BcPe0102_out	4.03E-05	3.59E-05	2.32E-05	1.35E-05	7.36E-06	3.83E-06	1.92E-06	9.39E-07	4.47E-07	2.12E-07	9.83E-08	4.50E-08	2.02E-08	9.14E-09	1.28E-04
	1	5 BcPe0105_out	4.40E-05	3.42E-05	2.20E-05	1.28E-05	7.02E-06	3.67E-06	1.84E-06	9.01E-07	4.30E-07	2.04E-07	9.50E-08	4.36E-08	1.94E-08	8.88E-09	1.27E-04
	1	10 BcPe0110_out	4.71E-05	3.14E-05	1.99E-05	1.16E-05	6.46E-06	3.40E-06	1.71E-06	8.44E-07	4.02E-07	1.92E-07	8.97E-08	4.12E-08	1.85E-08	8.46E-09	1.23E-04
	1	20 BcPe0120_out	4.71E-05	2.58E-05	1.63E-05	9.56E-06	5.46E-06	2.93E-06	1.48E-06	7.35E-07	3.52E-07	1.70E-07	8.00E-08	3.66E-08	1.66E-08	7.65E-09	1.10E-04
	1	50 BcPe0150_out	3.16E-05	1.38E-05	8.78E-06	5.25E-06	3.26E-06	1.85E-06	9.62E-07	4.86E-07	2.36E-07	1.16E-07	5.62E-08	2.58E-08	1.20E-08	5.64E-09	6.64E-05
	2	1 BcPe0201_out	3.75E-05	3.59E-05	2.30E-05	1.34E-05	7.28E-06	3.79E-06	1.89E-06	9.24E-07	4.39E-07	2.09E-07	9.68E-08	4.43E-08	1.96E-08	8.95E-09	1.25E-04
	2	2 BcPe0202_out	3.89E-05	3.53E-05	2.26E-05	1.32E-05	7.17E-06	3.74E-06	1.86E-06	9.12E-07	4.33E-07	2.06E-07	9.56E-08	4.37E-08	1.94E-08	8.88E-09	1.24E-04
	2	5 BcPe0205_out	4.17E-05	3.35E-05	2.13E-05	1.24E-05	6.82E-06	3.57E-06	1.78E-06	8.75E-07	4.17E-07	1.98E-07	9.23E-08	4.23E-08	1.87E-08	8.63E-09	1.23E-04
	2	10 BcPe0210_out	4.39E-05	3.06E-05	1.93E-05	1.13E-05	6.27E-06	3.31E-06	1.66E-06	8.18E-07	3.90E-07	1.86E-07	8.72E-08	4.00E-08	1.79E-08	8.22E-09	1.18E-04
	2	20 BcPe0220_out	4.28E-05	2.51E-05	1.58E-05	9.25E-06	5.29E-06	2.85E-06	1.44E-06	7.12E-07	3.41E-07	1.65E-07	7.78E-08	3.55E-08	1.60E-08	7.42E-09	1.04E-04
	2	50 BcPe0250_out	2.79E-05	1.34E-05	8.48E-06	5.07E-06	3.16E-06	1.79E-06	9.32E-07	4.70E-07	2.29E-07	1.13E-07	5.46E-08	2.49E-08	1.15E-08	5.49E-09	6.16E-05
	5	1 BcPe0501_out	3.36E-05	3.36E-05	2.10E-05	1.23E-05	6.67E-06	3.50E-06	1.72E-06	8.44E-07	4.00E-07	1.90E-07	8.89E-08	4.06E-08	1.78E-08	8.17E-09	1.14E-04
	5	2 BcPe0502_out	3.43E-05	3.29E-05	2.06E-05	1.20E-05	6.56E-06	3.44E-06	1.70E-06	8.32E-07	3.95E-07	1.88E-07	8.79E-08	4.00E-08	1.76E-08	8.10E-09	1.13E-04
	5	5 BcPe0505_out	3.57E-05	3.11E-05	1.93E-05	1.13E-05	6.23E-06	3.29E-06	1.63E-06	7.98E-07	3.80E-07	1.81E-07	8.48E-08	3.88E-08	1.70E-08	7.88E-09	1.10E-04
	5	10 BcPe0510_out	3.63E-05	2.81E-05	1.74E-05	1.02E-05	5.71E-06	3.04E-06	1.51E-06	7.45E-07	3.55E-07	1.69E-07	8.00E-08	3.66E-08	1.62E-08	7.50E-09	1.04E-04
	5	20 BcPe0520_out	3.42E-05	2.28E-05	1.41E-05	8.36E-06	4.81E-06	2.61E-06	1.31E-06	6.47E-07	3.10E-07	1.50E-07	7.12E-08	3.25E-08	1.44E-08	6.77E-09	8.95E-05
	5	50 BcPe0550_out	2.14E-05	1.21E-05	7.58E-06	4.58E-06	2.87E-06	1.64E-06	8.48E-07	4.26E-07	2.08E-07	1.02E-07	4.96E-08	2.28E-08	1.05E-08	4.97E-09	5.18E-05
	10	1 BcPe1001_out	2.75E-05	2.91E-05	1.75E-05	1.04E-05	5.66E-06	3.02E-06	1.47E-06	7.17E-07	3.41E-07	1.62E-07	7.63E-08	3.48E-08	1.53E-08	7.10E-09	9.60E-05
	10	2 BcPe1002_out	2.77E-05	2.85E-05	1.71E-05	1.01E-05	5.56E-06	2.97E-06	1.45E-06	7.08E-07	3.36E-07	1.60E-07	7.54E-08	3.44E-08	1.51E-08	7.05E-09	9.48E-05
	10	5 BcPe1005_out	2.81E-05	2.67E-05	1.61E-05	9.53E-06	5.28E-06	2.83E-06	1.38E-06	6.78E-07	3.23E-07	1.54E-07	7.29E-08	3.33E-08	1.46E-08	6.86E-09	9.11E-05
	10	10 BcPe1010_out	2.77E-05	2.39E-05	1.44E-05	8.60E-06	4.83E-06	2.62E-06	1.29E-06	6.32E-07	3.02E-07	1.45E-07	6.87E-08	3.15E-08	1.39E-08	6.53E-09	8.46E-05
	10	20 BcPe1020_out	2.52E-05	1.93E-05	1.17E-05	7.01E-06	4.06E-06	2.24E-06	1.11E-06	5.48E-07	2.64E-07	1.28E-07	6.11E-08	2.80E-08	1.25E-08	5.90E-09	7.16E-05
	10	50 BcPe1050_out	1.53E-05	1.02E-05	6.27E-06	3.85E-06	2.43E-06	1.41E-06	7.21E-07	3.61E-07	1.77E-07	8.72E-08	4.28E-08	1.96E-08	8.97E-09	4.28E-09	4.08E-05
	20	1 BcPe2001_out	1.87E-05	2.09E-05	1.18E-05	7.18E-06	4.00E-06	2.21E-06	1.05E-06	5.09E-07	2.45E-07	1.18E-07	5.58E-08	2.55E-08	1.12E-08	5.22E-09	6.68E-05
	20	2 BcPe2002_out	1.86E-05	2.04E-05	1.16E-05	7.03E-06	3.93E-06	2.17E-06	1.04E-06	5.02E-07	2.41E-07	1.17E-07	5.52E-08	2.52E-08	1.11E-08	5.17E-09	6.57E-05
	20	5 BcPe2005_out	1.82E-05	1.90E-05	1.08E-05	6.60E-06	3.73E-06	2.07E-06	9.91E-07	4.81E-07	2.32E-07	1.13E-07	5.31E-08	2.44E-08	1.07E-08	5.03E-09	6.24E-05
	20	10 BcPe2010_out	1.74E-05	1.70E-05	9.72E-06	5.95E-06	3.41E-06	1.92E-06	9.22E-07	4.48E-07	2.17E-07	1.05E-07	5.00E-08	2.33E-08	1.01E-08	4.84E-09	5.72E-05
	20	20 BcPe2020_out	1.52E-05	1.36E-05	7.86E-06	4.86E-06	2.87E-06	1.64E-06	7.97E-07	3.89E-07	1.91E-07	9.30E-08	4.44E-08	2.07E-08	9.09E-09	4.36E-09	4.76E-05
	20	50 BcPe2050_out	8.93E-06	7.20E-06	4.26E-06	2.69E-06	1.73E-06	1.03E-06	5.19E-07	2.57E-07	1.29E-07	6.39E-08	3.12E-08	1.47E-08	6.48E-09	3.18E-09	2.69E-05

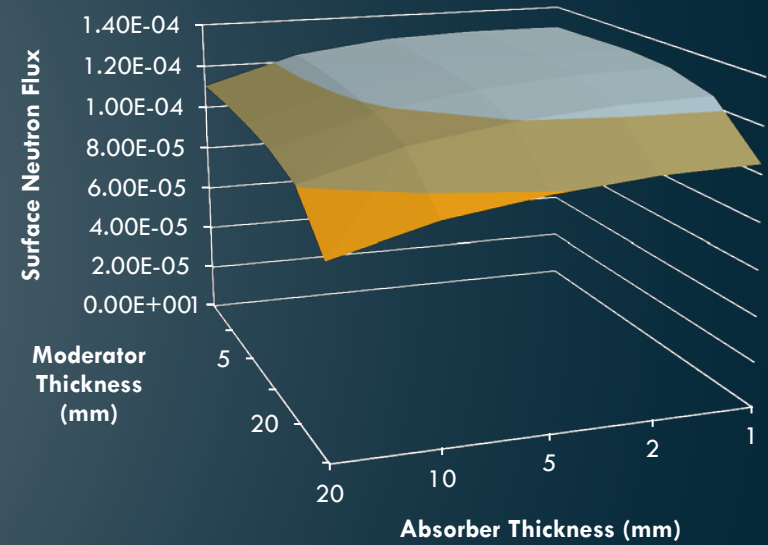
GdWa



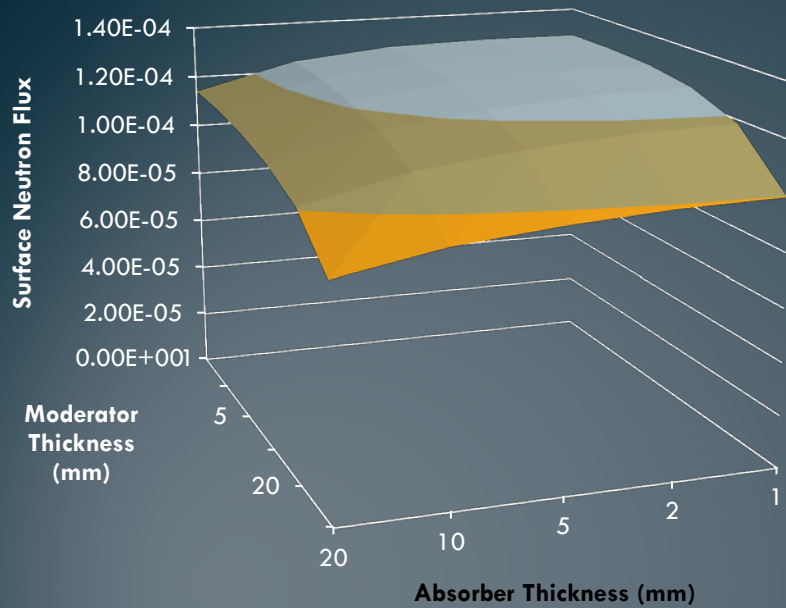
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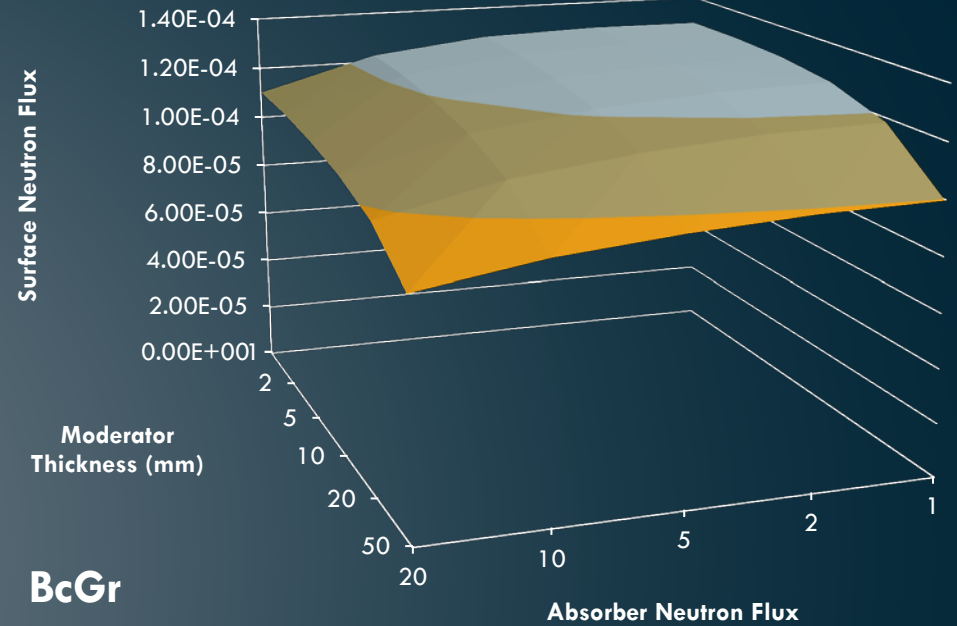
CdWa



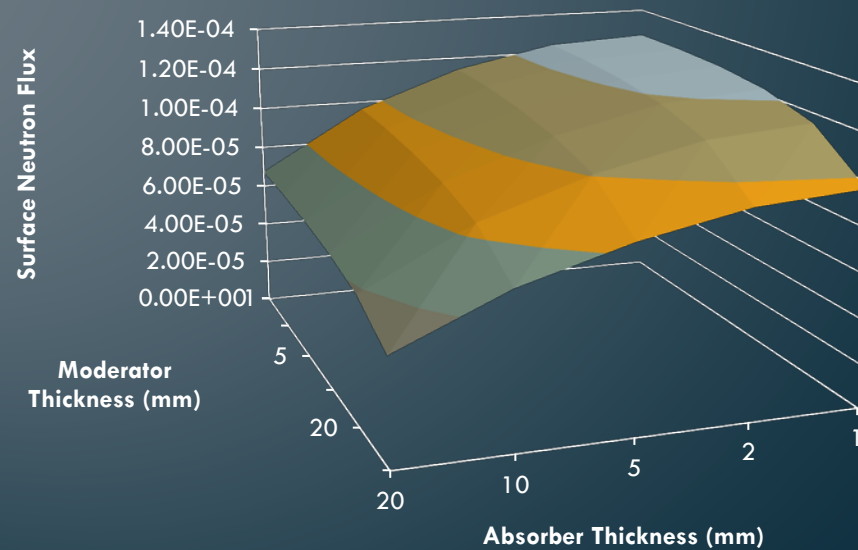
GdGr



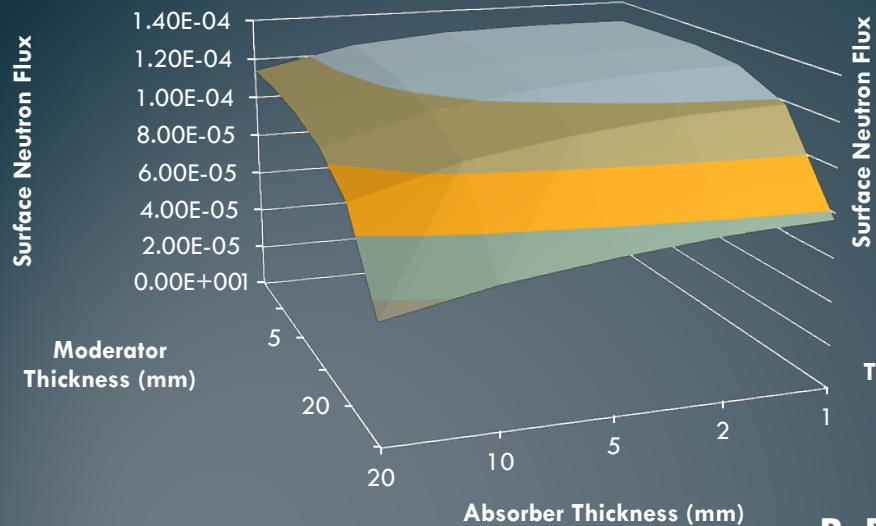
CdGr



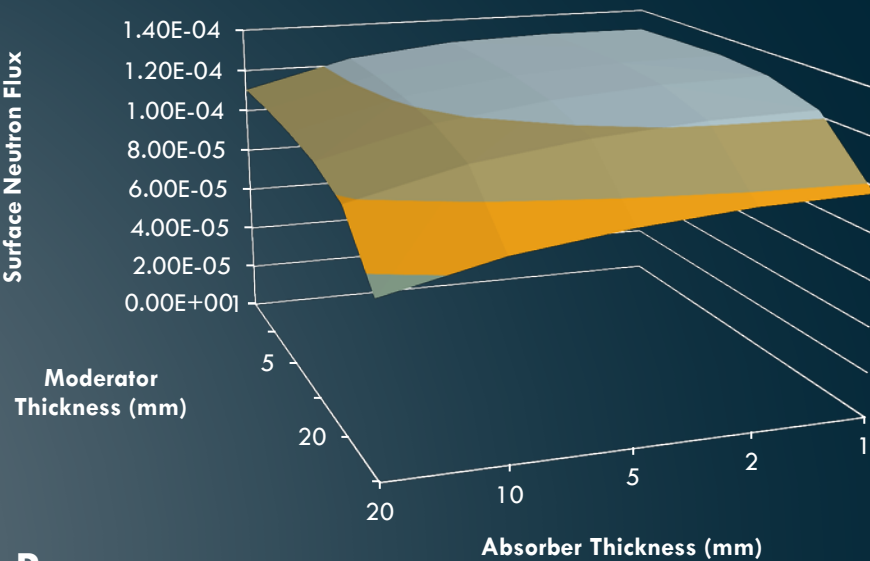
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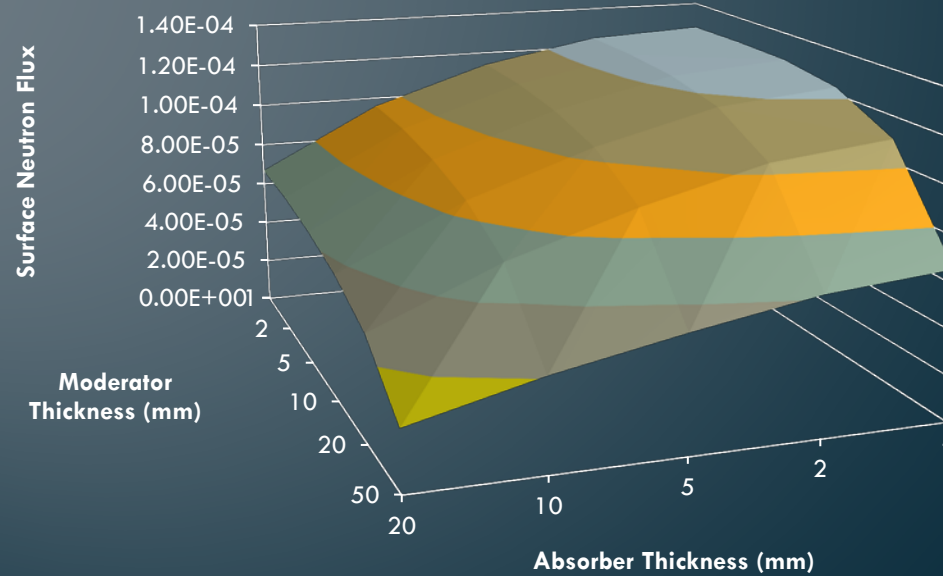
GdPe



CdPe



BcPe



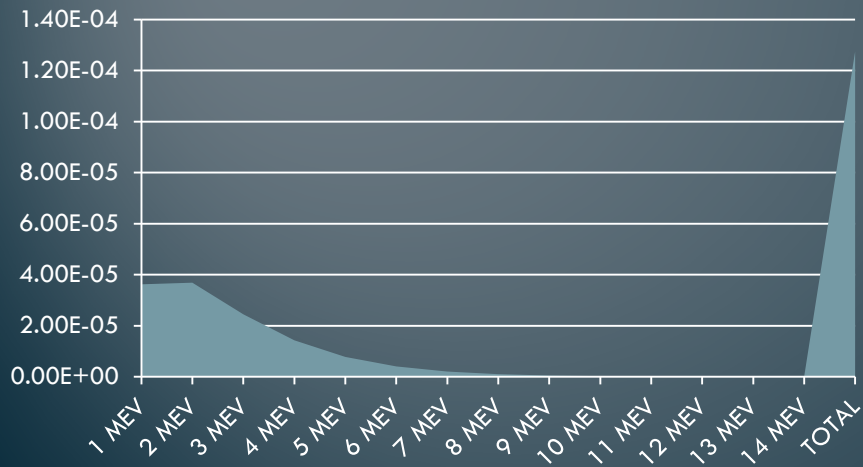
CONCLUSIONS

- Boron-Carbide acted as the best absorber
 - High neutron scattering cross-section
- Polyethylene was the best moderator
 - Dense Hydrogen concentration
- Optimal Geometry maybe at 10 mm absorber thickness with 20 mm moderator thickness (Greatest Slope Change)

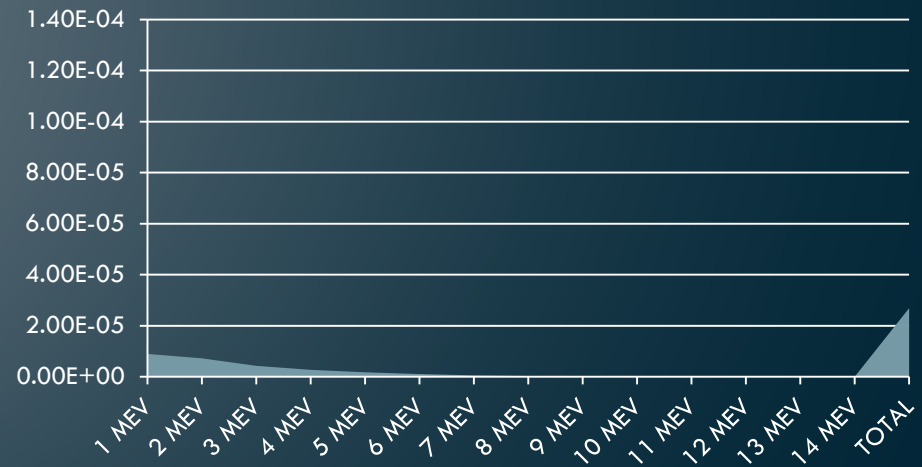
Future

- Multi-Source detection
- Denser moderator (Surface Area/compression)(5)
- Greater Particle Simulations

No Shield



BcPe2050_out



RESOURCES

1. <http://neutron.kth.se/courses/transmutation/Spectra/Spectra.html>
2. http://webcache.googleusercontent.com/search?q=cache:t4WNOO50H7QJ:www.researchgate.net/publication/236509948_Neutron-induced_235U_fission_spectrum_measurements_using_liquid_organic_scintillation_detectors/file/50463518a8cbabfbb5.pdf+&cd=6&hl=en&ct=clnk&gl=us&client=firefox-a
3. <http://www.cvmb.colostate.edu/erhs/Health%20Physics/Craig%20Bias%20Optimizing%20The%20Detection-Bias-May%2002.pdf>
4. <http://www.fas.org/sgp/othergov/doe/lanl/lib-www/la-pubs/00326407.pdf>
5. <http://www.osti.gov/scitech/servlets/purl/442164>
6. <http://web.mit.edu/8.13/www/tgm-neutron-detectors.pdf>