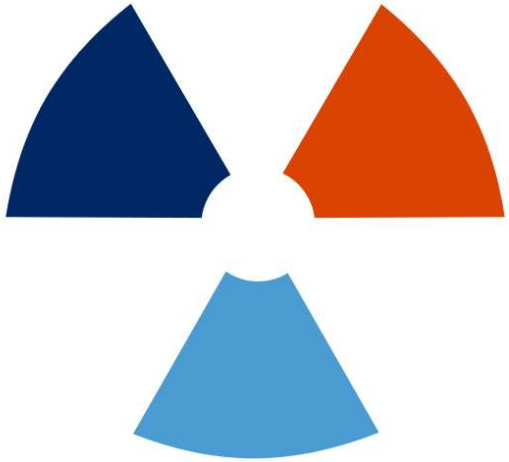

VARSKIN Limitations

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Oregon State University

Work supported by the U.S. Nuclear Regulatory Commission (NRC), Office of Nuclear Regulatory Research (RES), under contracts NRC-HQ-60-15-R-0017 and 31310018C0026.

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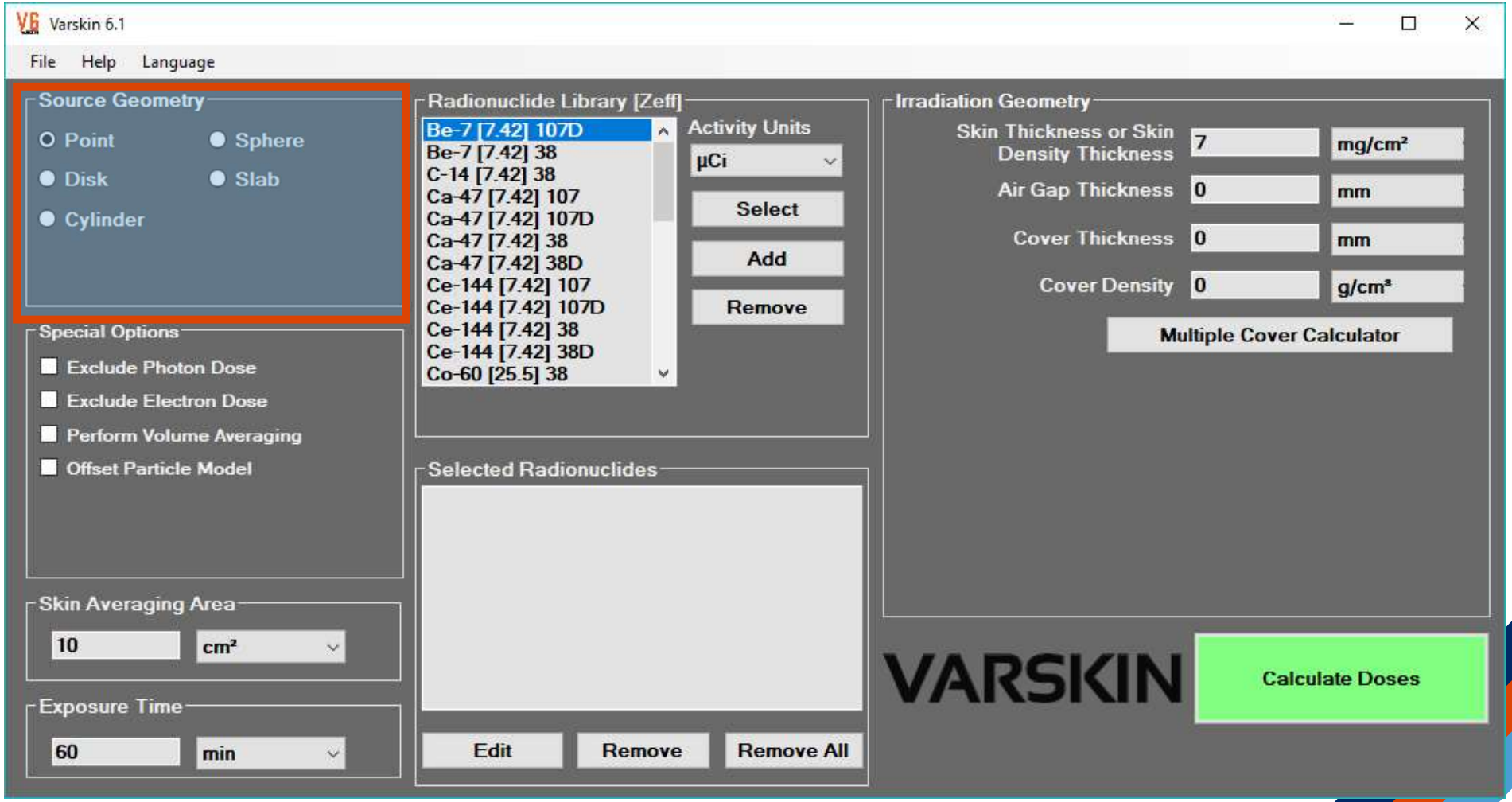

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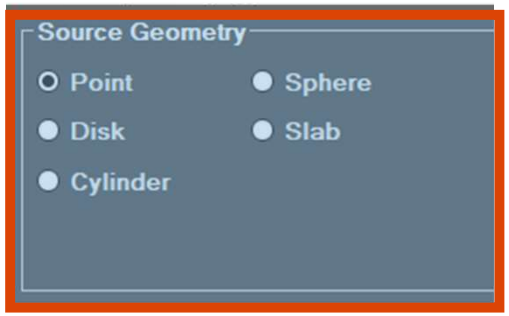
Source Geometry



- Point, 2D disk, and 3D source configurations available
- When selected, dimensions are requested in a separate section of the input window
- Computational time is shortest for point sources and increases with 2D and 3D geometries
- Volumetric sources implement point kernel calculations for up to 3,375 source points (15 x 15 x 15)
- Point-source and 2D disk behavior is very well characterized and is shown to be in good agreement with other calculational methods*
- The code is weak (~50%) when considering an air-gap or the source is on clothing or otherwise above the skin

*Anspach & Hamby. Performance of the VARSKIN 5 (V5.3) Electron Dosimetry Model. *Radiation Protection Dosimetry*. doi:10.1093/rpd/ncx302. January 2018.
*Dubeau et al. A Comparison of Beta Skin Doses Calculated with VARSKIN 5.3 and MCNP5. *Radiation Protection Dosimetry*. doi:10.1093/rpd/ncy108. July 2018.

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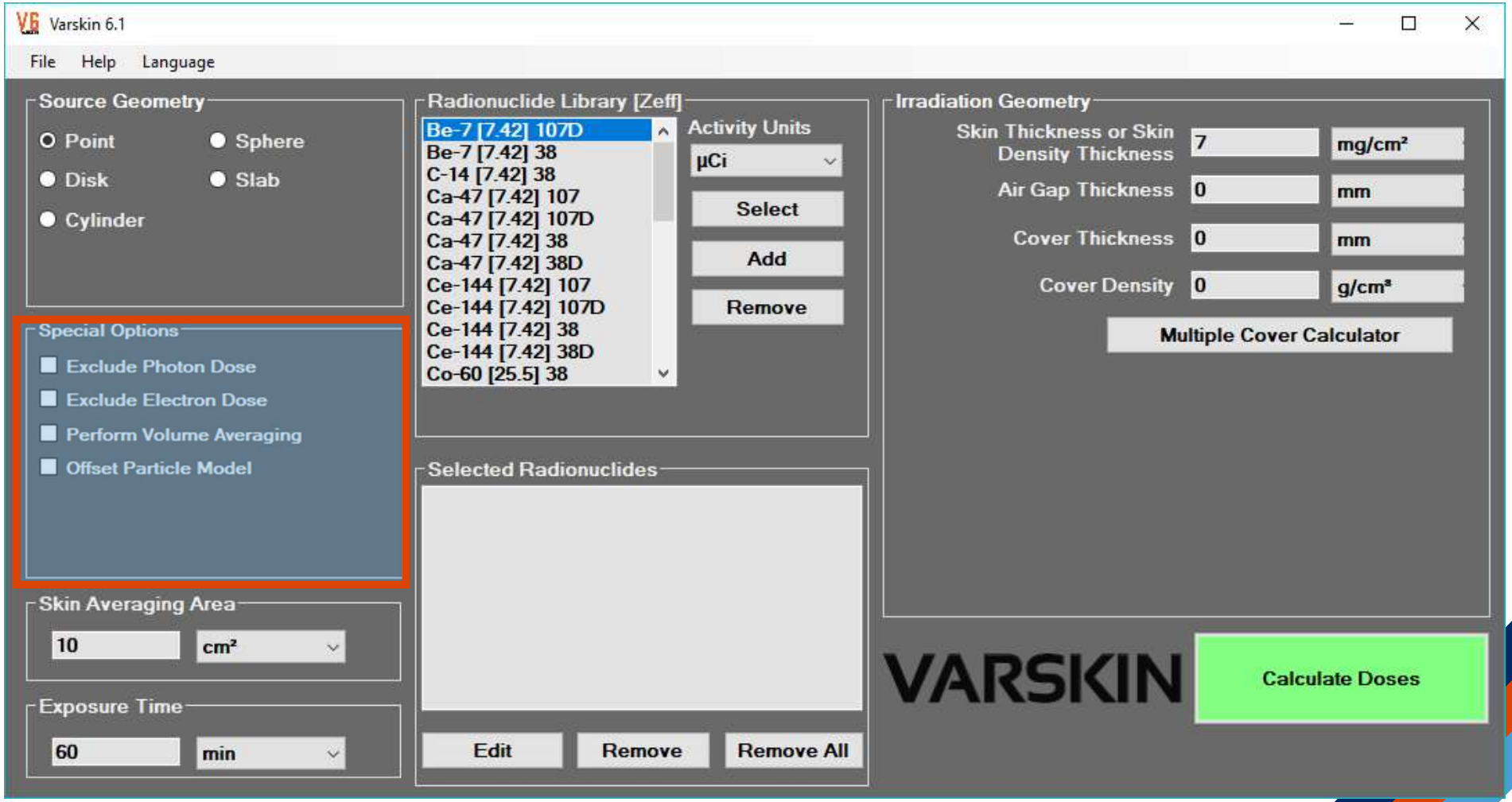
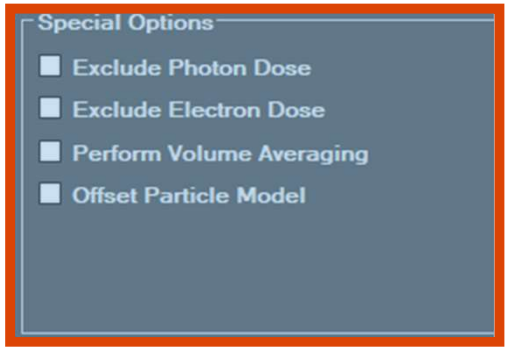


Special Options



- Photon dosimetry confirmed with MCNP5 simulation
  - 10 keV to 3 MeV – VARSKIN 4
- Electron dosimetry confirmed w EGSnrc simulation
  - 10 keV to 8 MeV, with 7.42 (H_2O) < Z < 92 (Pu) – VARSKIN 5
  - accuracy decreases as depth reaches the CSDA range
- VARSKIN always assumes air is above the source
  - caution: many works in the literature assume a water sphere
- Volume averaging is influenced by zero doses at depth
- Offset particle model available only for photon point sources – used in the case of multiple overlapping sources

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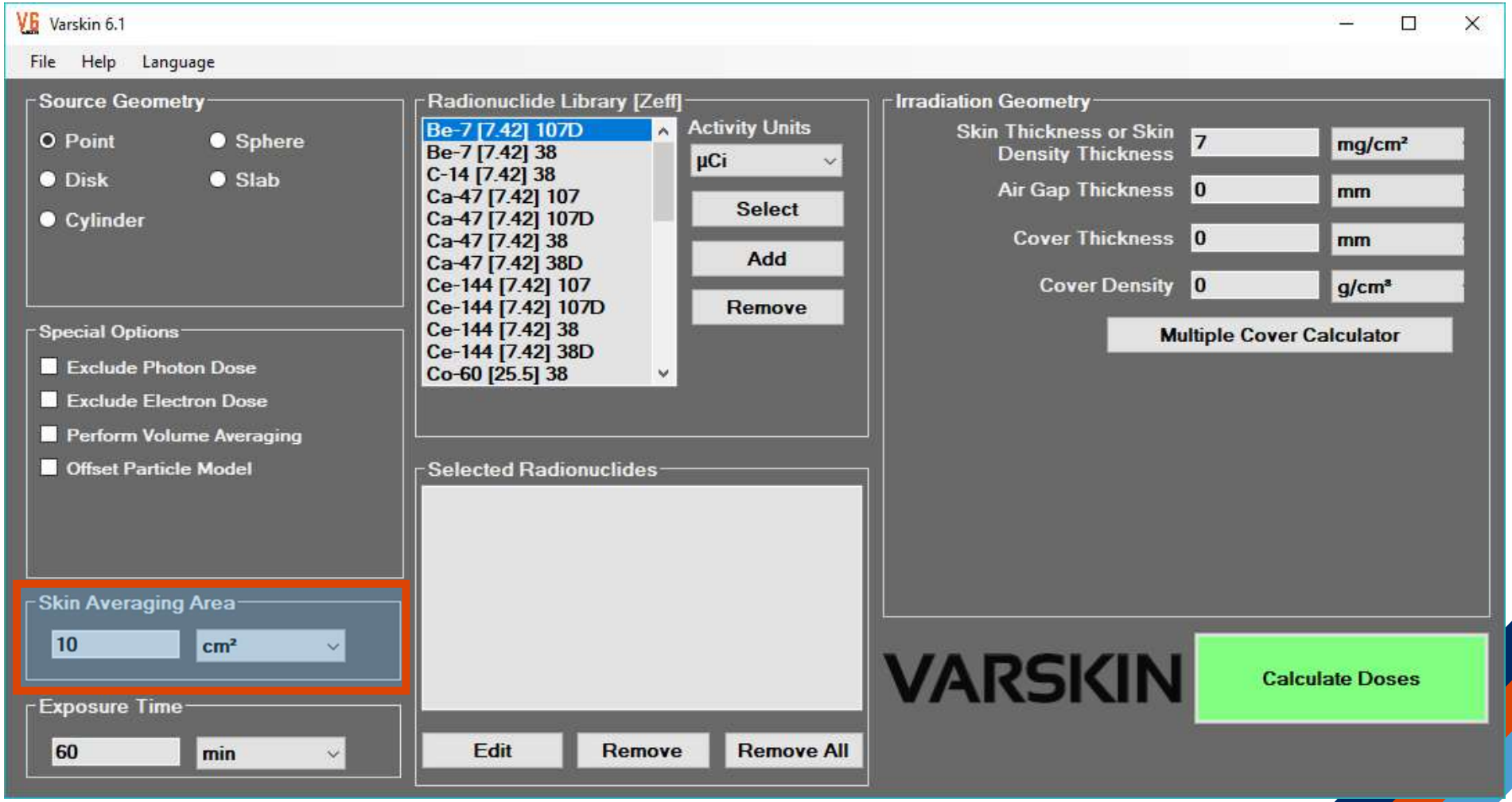
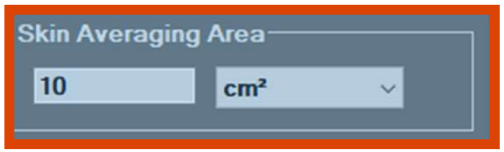
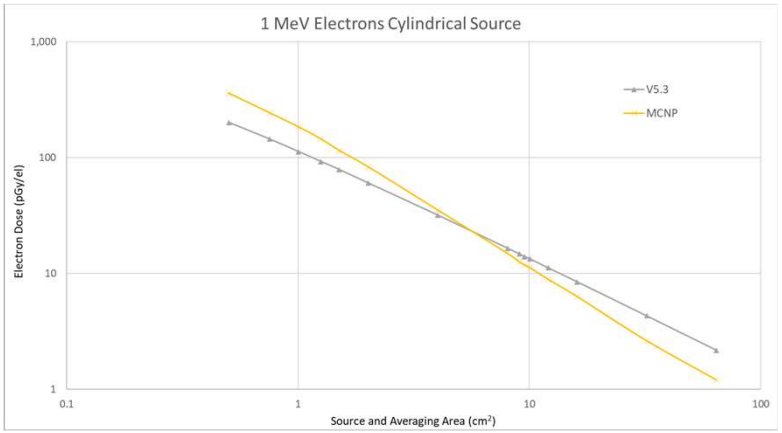
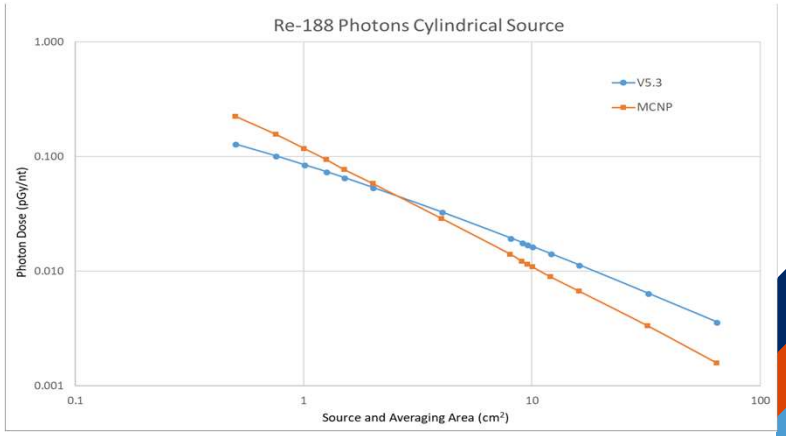


Skin Averaging Area

- Area over which dose is averaged
  - limited to areas between 0.01 cm^2 and 100 cm^2
- Backscatter factors determine specifically for 1 cm^2 and 10 cm^2
  - interpolated/extrapolated otherwise







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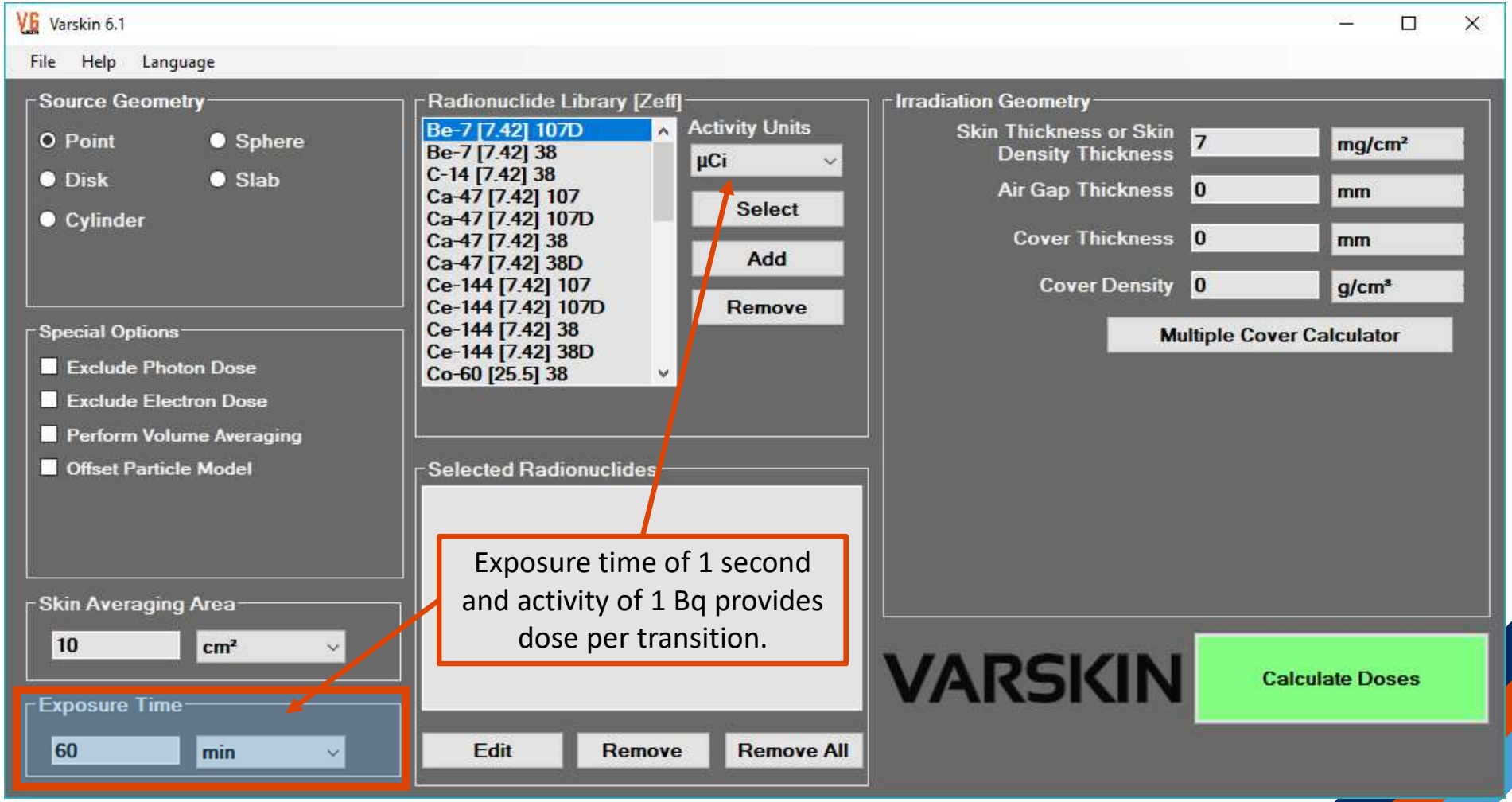

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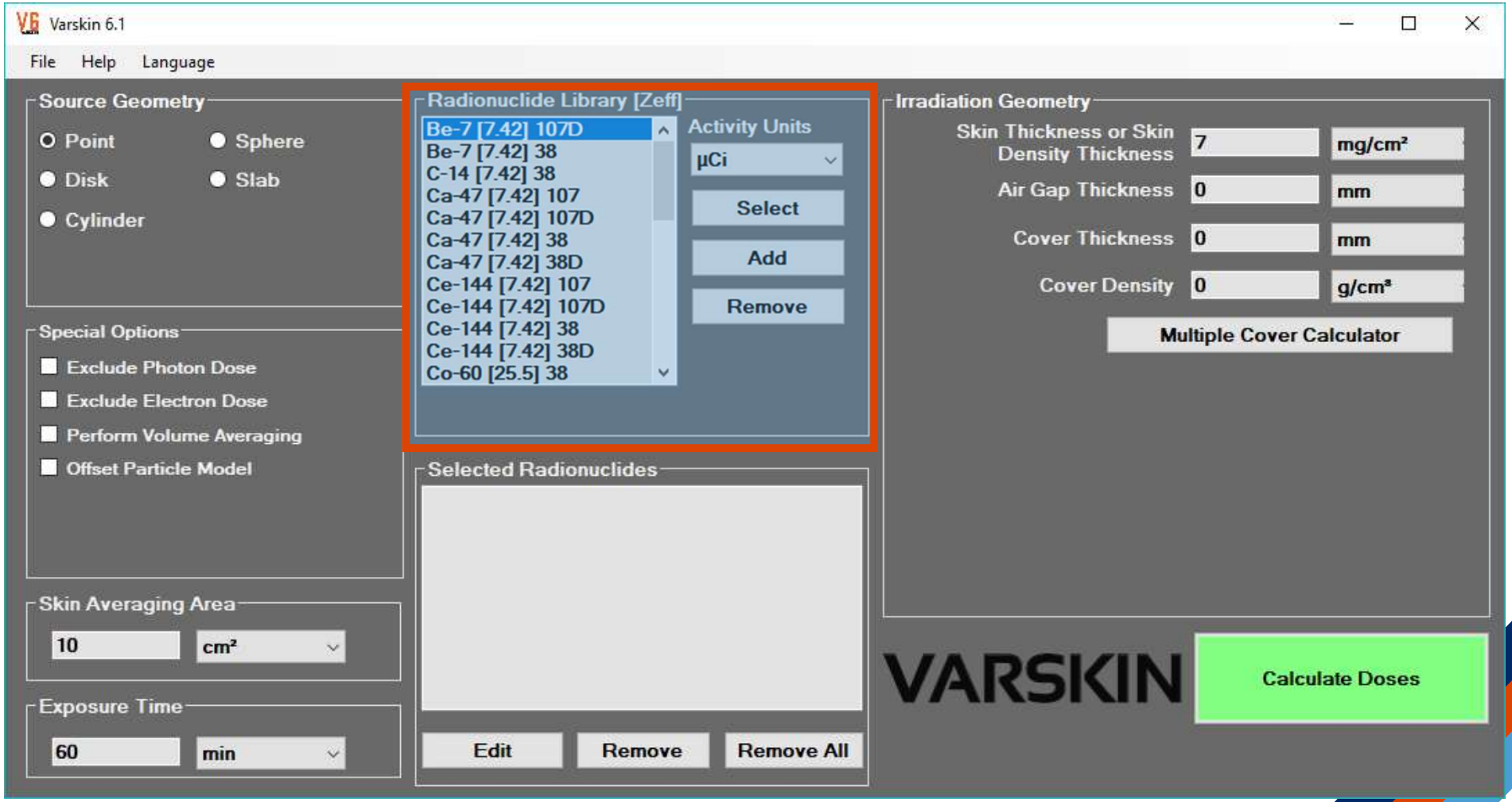

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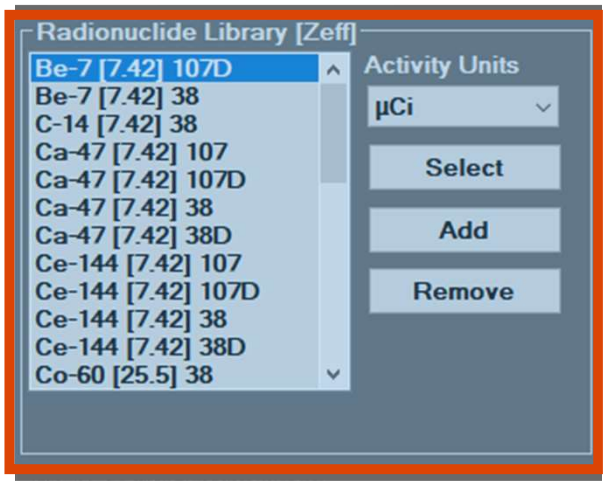
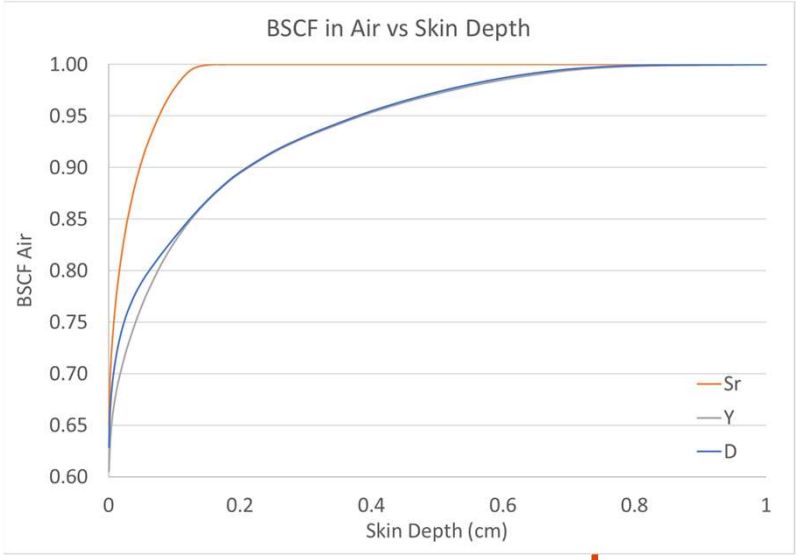
Radionuclide Library

- Monoenergetic particles
  - photons: 1 keV to 3 MeV
  - electrons: 1 keV to 8 MeV
- Four options
  - 38/38D/107/107D
- (D) includes branching ratios greater than 1%
- All progeny (D) are assumed to be in ***equilibrium*** with the parent





- "No Decay" dose option is provided for the situation of secular equilibrium, for example $^{137}Cs/^{137m}Ba$
- When considering progeny (D), the resulting SADD is a conglomerate of parent/daughter distributions, and the resulting X_{90}, backscatter factors, etc. may introduce differences in dose
- Prominent differences ($^{90}Sr/Y$) in dose, however, are less than a few percent

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^{114}In Electron Emission Data

- Greatest change in inhalation dose*
- For a ^{114}In point source, shallow electron dose increases in VARSKIN by more than **4x** from ICRP 38 to 107
  - ICRP 38 electron dose = 97.8 pGy/nt
  - ICRP 107 electron dose = 434 pGy/nt
- There's a great deal of change noticed in the dose distribution and the backscatter correction factors
- Databases indicate no photons

Electron Data

- ICRP 38
  - Avg E = 0.233 MeV
  - X_{90} = 0.083 cm
- ICRP 107
  - Avg E = 0.778 MeV
  - X_{90} = 0.432 cm

*Manabe, K.; Endo, A.; Eckerman, K.F. Impact of the New Nuclear Decay Data of ICRP 107 … *Radiation Protection Dosimetry*. 138(3):245-250. 2010.

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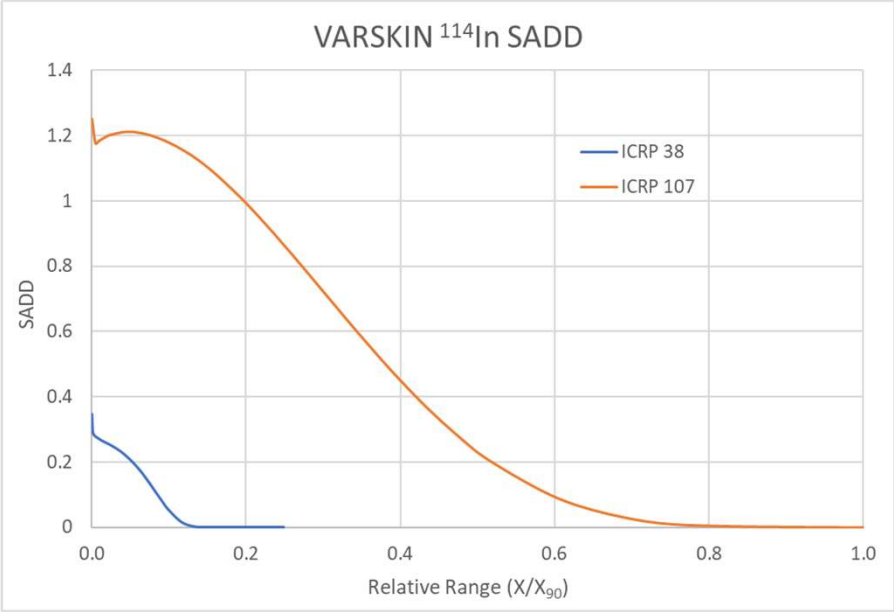
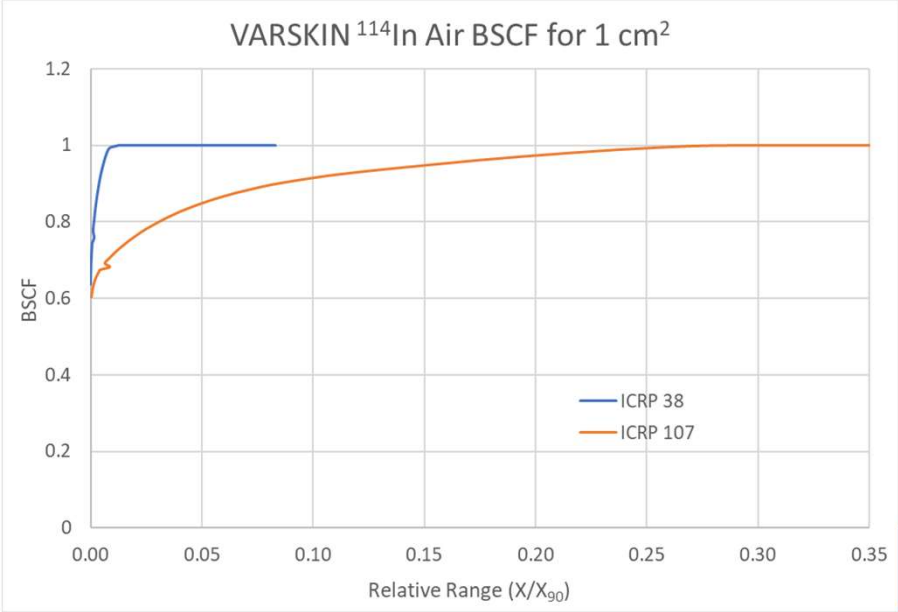
^{114}In VARSKIN SADD & BSCFs

Specific Absorbed Dose Distribution



Backscatter Correction Factors



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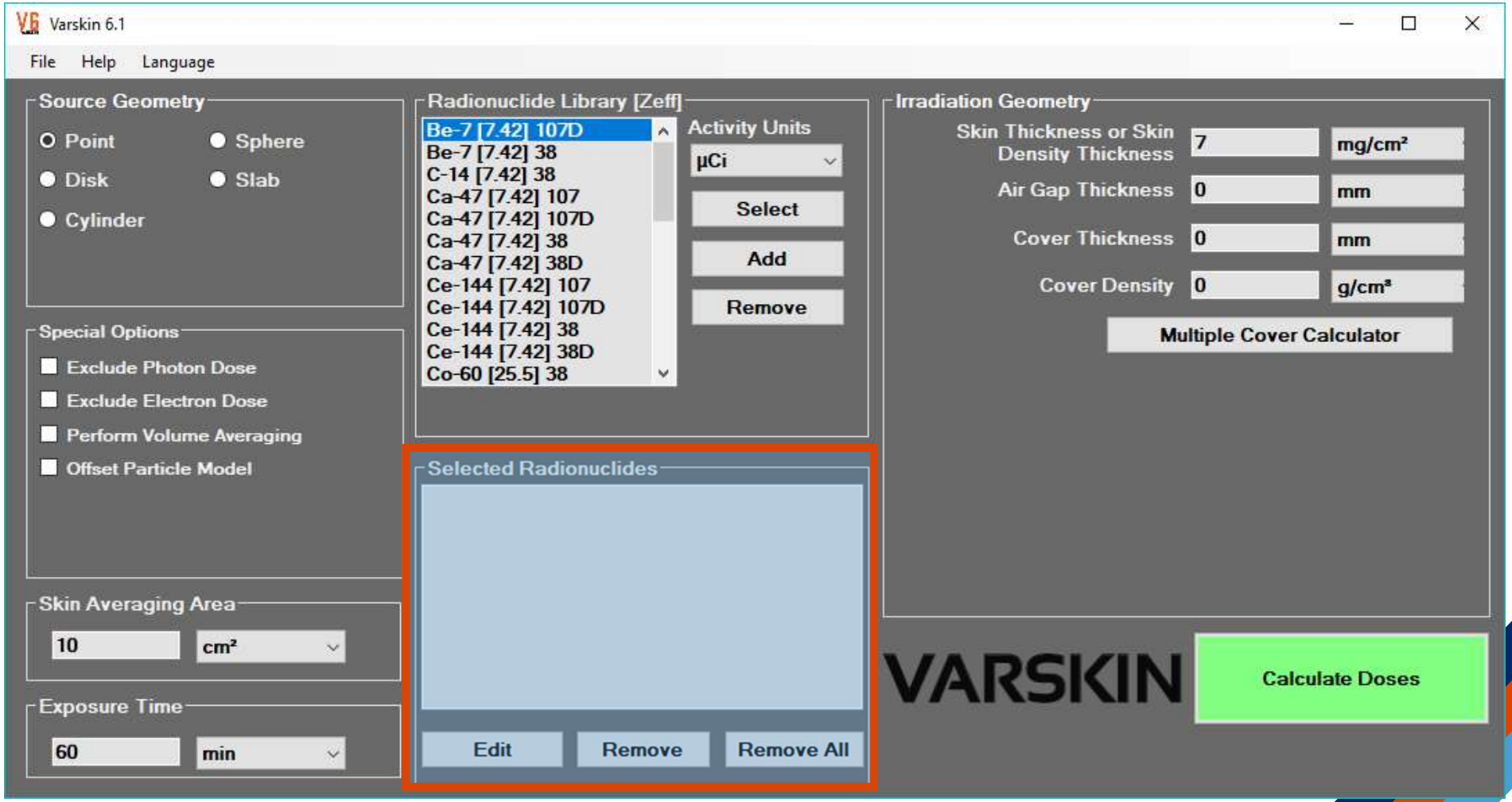

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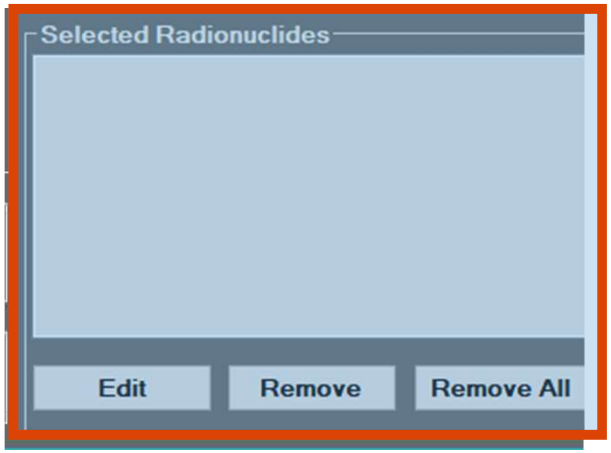
Selected Radionuclides

- Radionuclides are “selected” for the exposure scenario
  - they appear in this window
- The user can select a maximum of 20 nuclides per scenario
- A portion of Example #4 from the NUREG follows …
  - to show how the (D)aughter nuclides are handled



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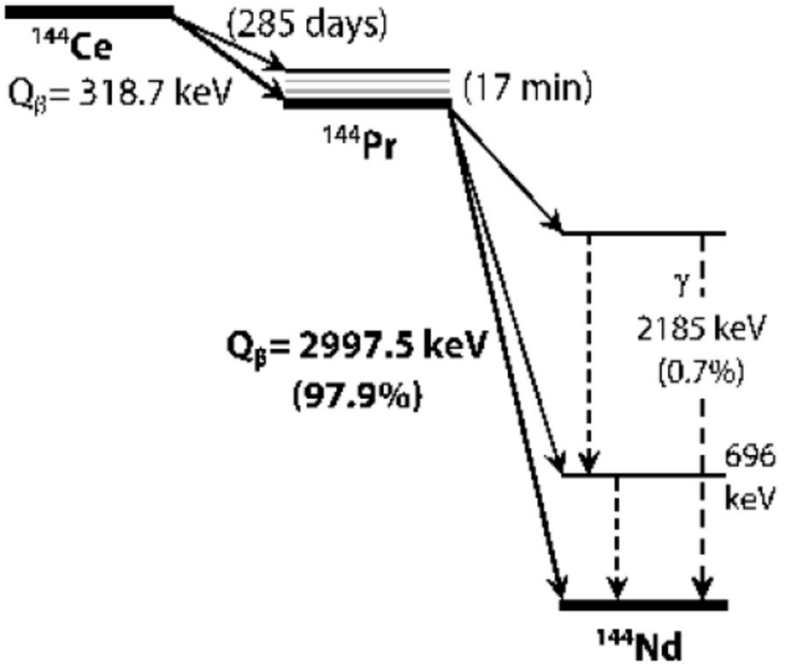
^{144}Ce Contamination Source

- 2D disk source of ^{144}Ce on the skin
- ^{144}Ce and its progeny, ^{144}Pr, transition through β^- decay
- The metastable state, ^{144m}Pr, occurs in about 2% of transitions
- Branching ratios for each possibility are considered individually and for the cumulative dose calculation



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ICRP 38 Electron Emissions from ^{144}Ce/Pr

Nuclide	HL (hrs)	Yield (%)	Avg Energy (MeV)	Electron X90 (cm)
Ce144	6823.2	1.57344	0.09230879	0.02774469
Pr144	0.288	1.0006	1.2079	0.695699
Pr144m	0.12	3.37682	0.617	0.004115152
Ce144(D)	6823.2	1.57344	0.654206	0.682593

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ICRP 38 Photon Emissions from ^{144}Ce/Pr

Manual

Nuclide	Branching	Yield (%)	Energy (MeV)
Ce144	1.000	1.6416	0.0801199
		10.8	0.13353
		5.40195	0.0360263
		2.95756	0.0355502
		1.06958	0.0407484
Pr144	0.9822	1.48	0.69649
Pr144m	0.0178	15.7456	0.0360263
		8.62071	0.0355502
		3.11763	0.0407484
		1.25177	0.0417924
		1.60605	0.0406532
		4.53392	0.00503329
		1.63137	0.00548929
Pr144*	0.999	1.48	0.69649

Automatic

Nuclide	Yield (%)	Energy (MeV)
Ce144(D)	1.6416	0.0801199
	10.8	0.13353
	5.40195	0.0360263
	2.95756	0.0355502
	1.06958	0.0407484
	1.45366	0.69649
	0.280272	0.0360263
	0.153449	0.0355502
	0.05549381	0.0407484
	0.02228151	0.0417924
	0.02858769	0.0406532
	0.08070377	0.00503329
	0.02903838	0.00548929
	0.02631766	0.69649

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ICRP 38 VARSKIN 6 Dose Results

Nuclide	Branching	Electron Dose (pGy/nt)	Photon Dose (pGy/nt)
Ce144	1.000	2.40	0.00363
Pr144	0.9822	4.58	0.000778
Pr144m	0.0178	0.000555	0.0142
Pr144*	0.999	4.58	0.000778
SUM		**6.98**	**0.00466**
Ce144(D)		**6.93**	**0.00466**
difference		-0.7%	0%

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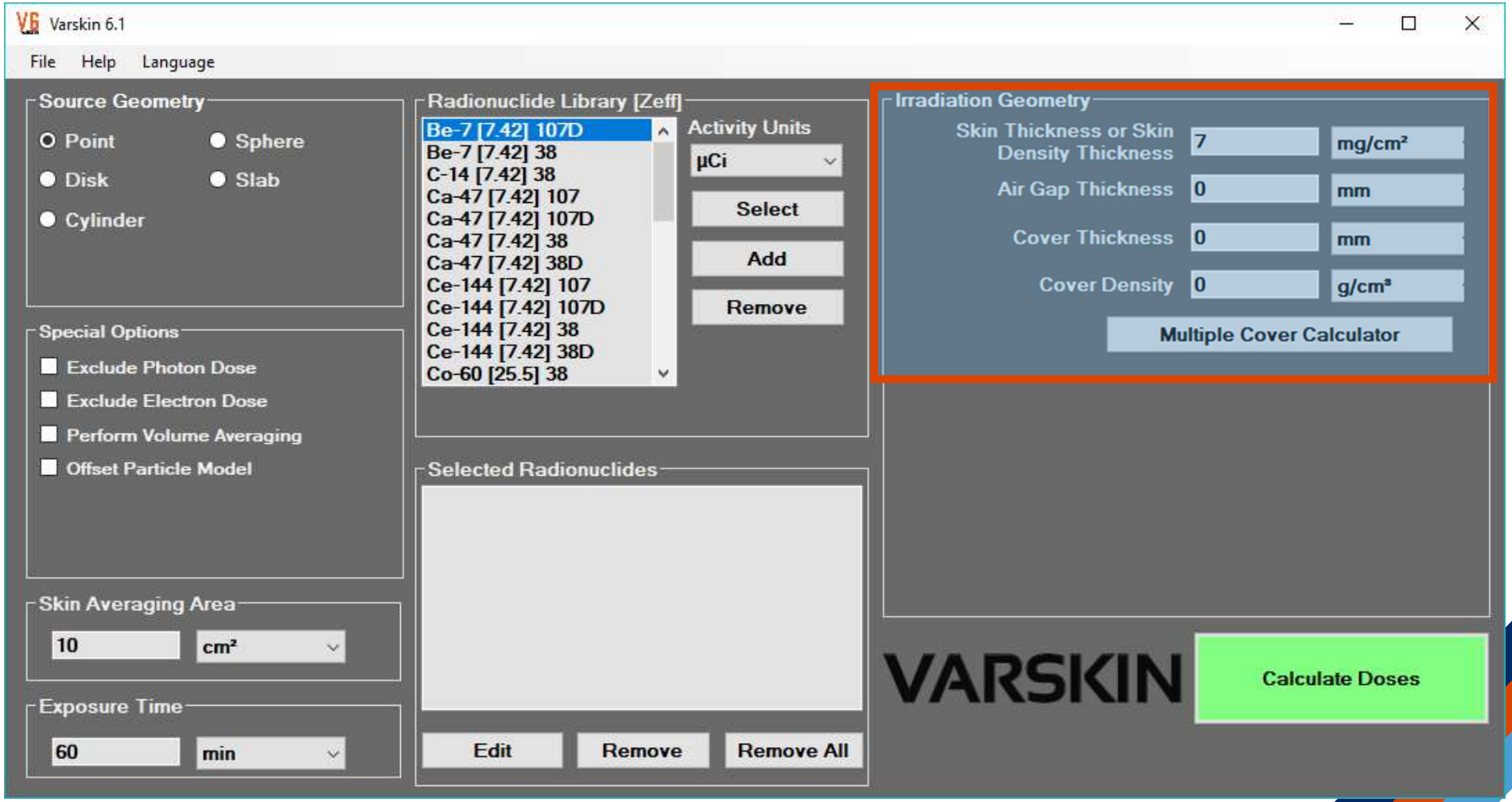

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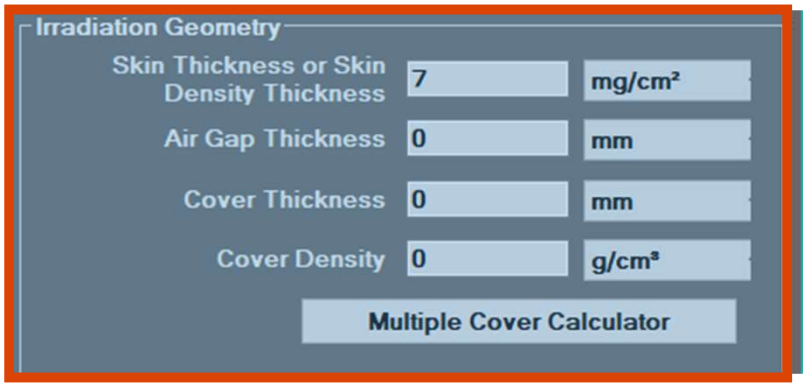
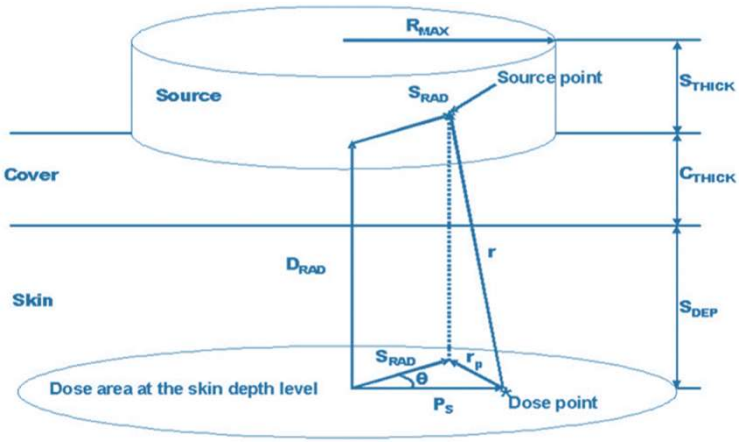
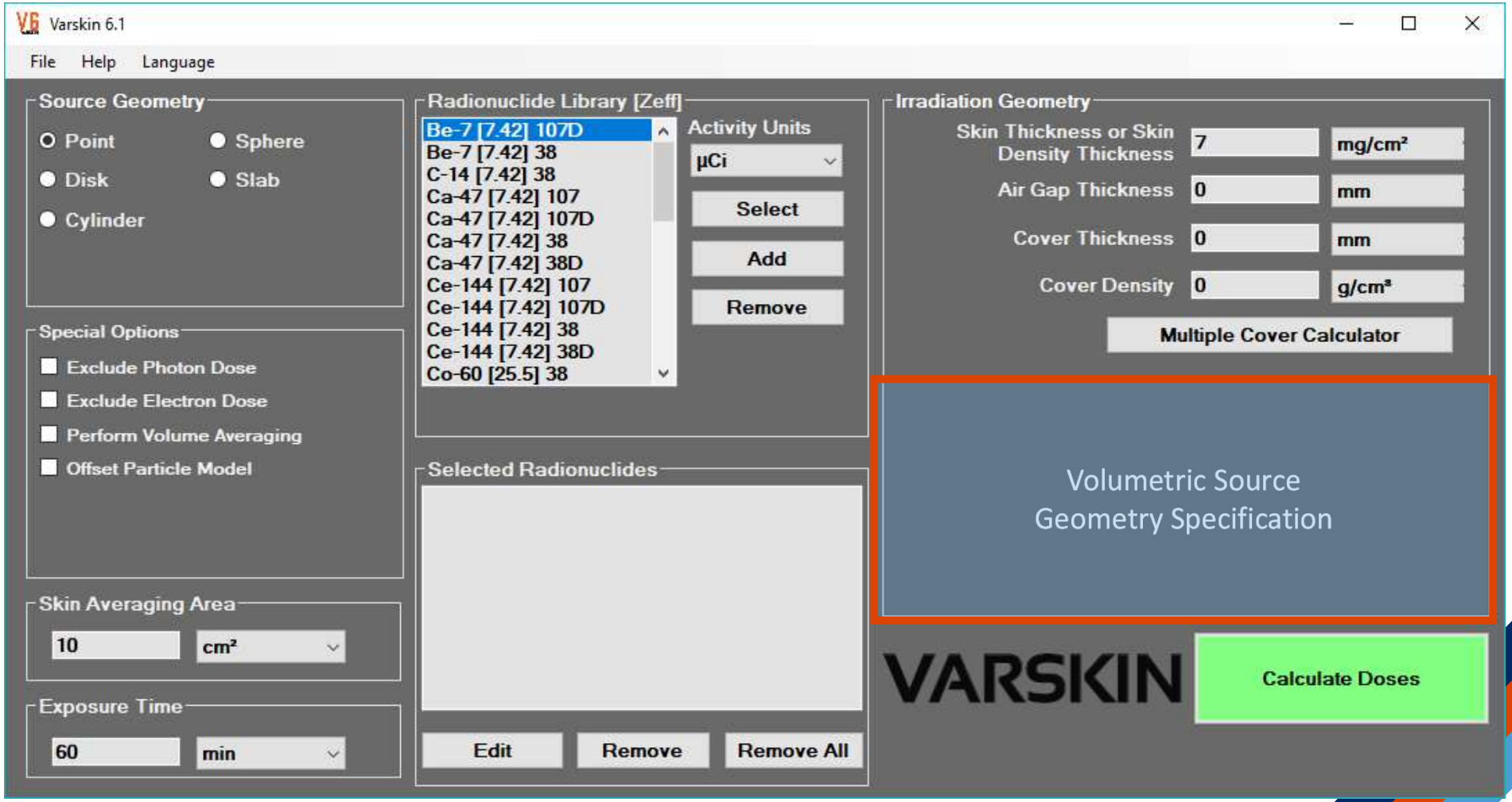
Irradiation Geometry

- Original intention is to estimate shallow skin dose (@ 7 mg/cm^2)
- Max source-to-skin distance (20 cm)
- Air-gap model has been shown to be unstable; these features should be used with caution
- Cover materials assumed to be either latex (ρ <= 1.25 g/cm^3) or cotton (ρ > 1.25 g/cm^3)
- Covers without an air-gap shown to be moderately acceptable
  - since no significant break in buildup






Varskin 6.1
File
Help
Language
Source Geometry
Point
Sphere
Disk
Slab
Cylinder
Special Options
Exclude Photon Dose
Exclude Electron Dose
Perform Volume Averaging
Offset Particle Model
Skin Averaging Area
10
cm²
Exposure Time
60
min
Radionuclide Library [Zeff]
Be-7 [7.42] 107D
Be-7 [7.42] 38
C-14 [7.42] 38
Ca-47 [7.42] 107
Ca-47 [7.42] 107D
Ca-47 [7.42] 38
Ca-47 [7.42] 38D
Ce-144 [7.42] 107
Ce-144 [7.42] 107D
Ce-144 [7.42] 38
Ce-144 [7.42] 38D
Co-60 [25.5] 38
Activity Units
µCi
Select
Add
Remove
Selected Radionuclides
Edit
Remove
Remove All
Irradiation Geometry
Skin Thickness or Skin Density Thickness
7
mg/cm²
Air Gap Thickness
0
mm
Cover Thickness
0
mm
Cover Density
0
g/cm³
Multiple Cover Calculator
Volumetric Source Geometry Specification
VARSKIN
Calculate Doses

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Volumetric Source Geometry

- Photon dosimetry – 3D sources modeled as air
  - can be influential for source dimensions > 1 mm
- Electron dosimetry – 3D sources default as water
  - can be influential for energies less than a few hundred keV
  - … and dimensions > 1 micron
  - consider changing effective Z (default = 7.42)
- Not intended for large dimensions
  - no more than ~1 mm for 3D source dimensions

Volumetric Source Geometry Specification

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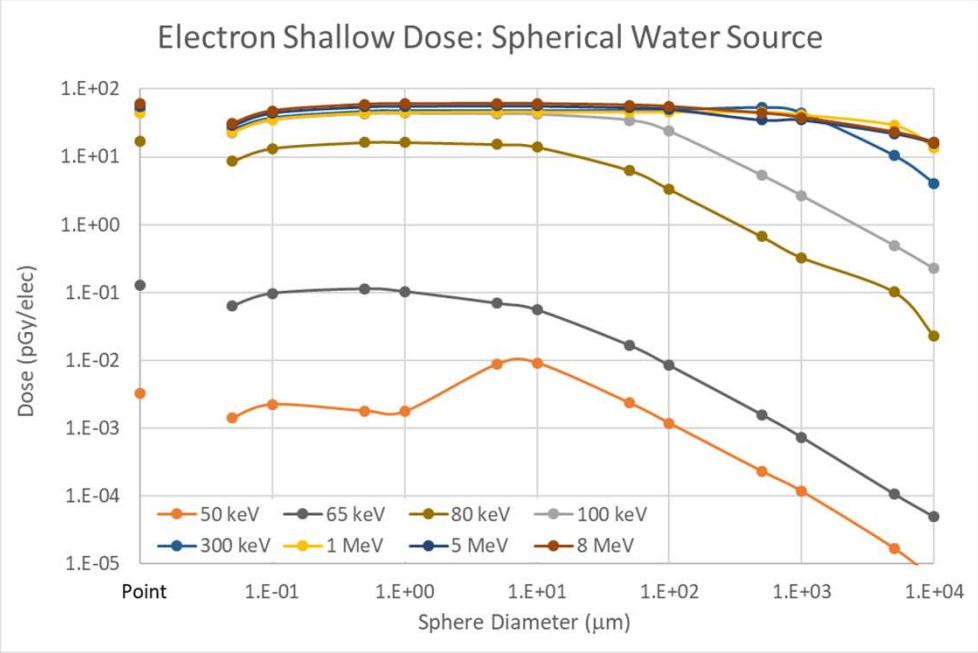
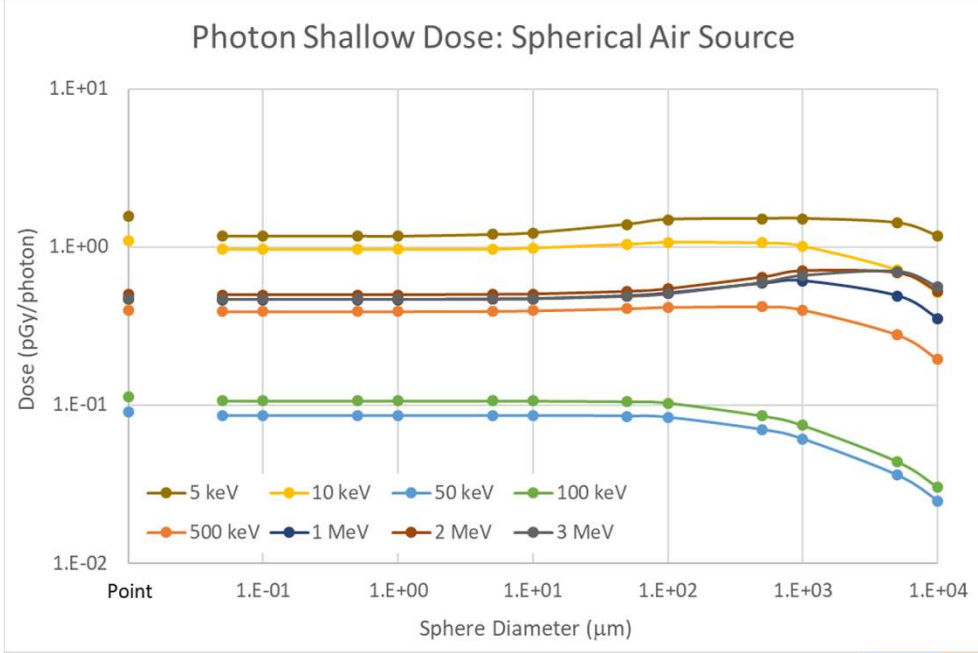
3D Source Dimensions and Shallow Dose





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Recent Contamination Event #1

Flourine-18

- PET mishap results in fluorodeoxyglucose (FDG) contamination on patient's shirt
- V6.1 assumptions: 15 mCi ^{18}F; 2-hr exposure; 100 cm^2 disk source; shirt 0.04 cm thickness, 0.9 g/cm^3 density (from NUREG); ICRP 38 database; 10 cm^2 averaging
- 7.7 Gy skin dose – if shirt is 'source' (96% from positrons)
  - 3.6 Gy – if shirt is 'cover'
  - 13 Gy – if directly on skin
  - ICRP 107 results are 3% lower
- patient allowed to visit cafeteria with FDG on their shirt
- medical facility estimated dose of 2.8 Gy "with great uncertainty"

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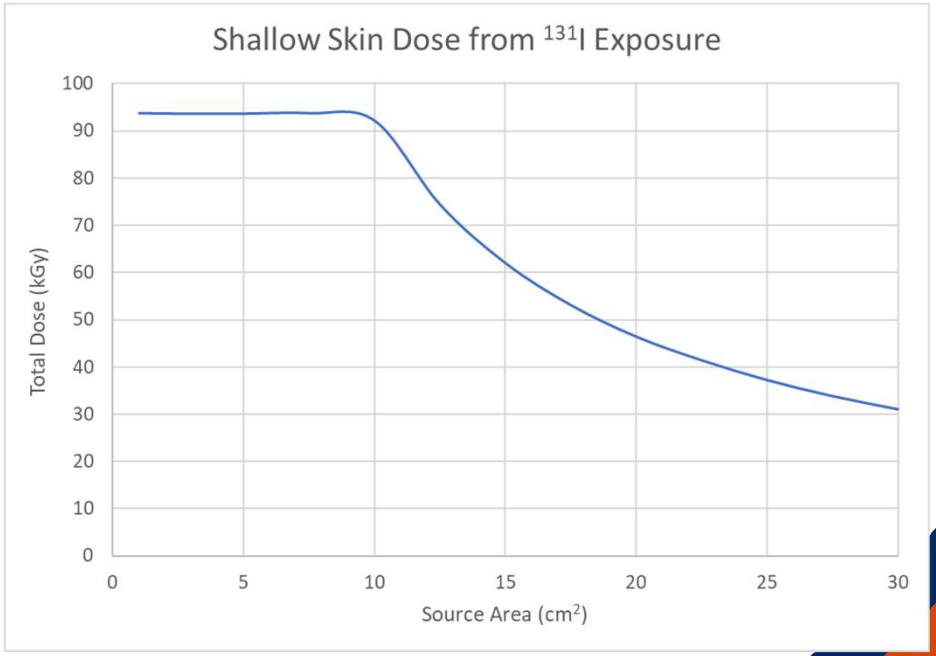
Recent Contamination Event #2

Iodine-131

- infusion procedure mishap resulting in metaiodobenzylguanidine (MIBG) skin contamination 'over the weekend'
- V6.1 assumptions: 420 mCi ^{131}I; 48-hr exposure; 15 cm^2 disk source; directly on the skin; ICRP 38; 10 cm^2 avg
- 62 kGy skin dose (99% from electrons)
  - ICRP 107 results are the same
- patient developed erythematous lesions and grade 3 desquamation w/in 3 days



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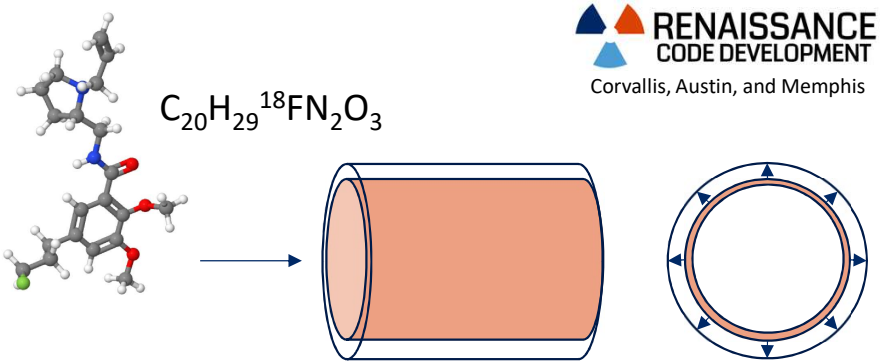
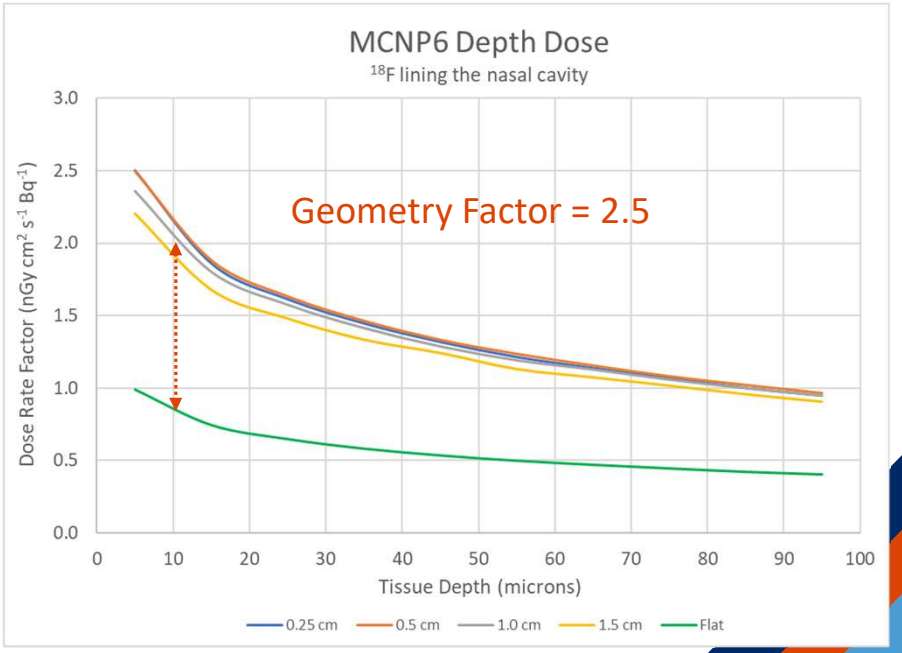
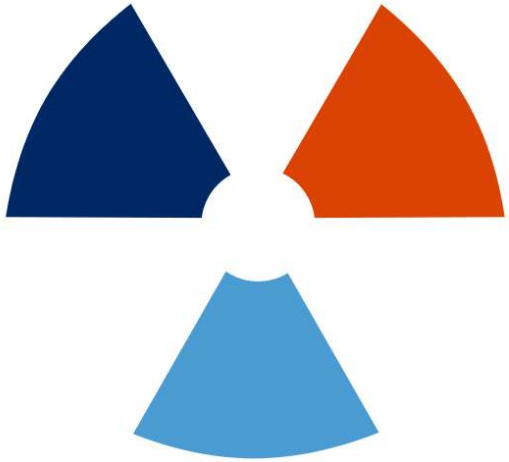
Unusual VARSKIN Usage



- ^{18}F PET radiotracer sprayed into the nose
  - "fallypride" administered in this fashion to bypass the blood-brain barrier, thus traveling directly to the brain
- What is dose to the nasal cavity?
- VARSKIN simplest case:
  - 150 cm^2 nasal-cavity surface laid flat
  - dose at 10 μm averaged over 10 cm^2
  - 0.76 nGy/sec per Bq/cm^2
    - 99% from positrons
- MCNP dose-rate factor
  - varying internal radii; dose at 10 μm
  - 2.1 nGy/sec per Bq/cm^2





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