Comparison of Monte Carlo codes MCNP and MONACO

for applying to shielding calculation of transport/storage casks

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- Comparison of feature (MCNP & MONACO)
- Comparison of calculated results
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BACKGROUND

- To design transport/storage casks for spent fuels with maximum capacity, shielding calculation is the most important.
- Monte Carlo codes may be the most powerful tool.

Problem

- So far, there are still difficulties to obtain reasonable and reliable results without many trials.
- What is good option to have reliable results without many trials?

PURPOSE

- Comparison of MCNP and MONACO
- Viewpoint of user of shielding calculation of casks based on the author's experiences

- MCNP : Los Alamos National Laboratory (LANL)

  :long history, many experience

  : most popular Monte Carlo code, now

- MONACO with MAVRIC : Oak Ridge National Lab. (ORNL)

  :new comer, but origin is MORSE

  :belong to SCALE 6

Comparison of feature
INPUT DATA

Item		MCNP	MONACO
Library		Continuous	Multi-group (200n+47g,27n+19g)
Geometry	Definition	Easy/ complicated	Easy
	Expression	Any	Limited
Source	No. of source region	Any	Limited
	Source distribution	Any	Uniform only (plan to prepare)
	Definition	Flexible, but complicated	Limited, but easy
Tally	Coordinate	Any	Cartesian only
	Dose Conversion factor	Not prepared	Prepared
	Definition	Flexible, but complicated	Limited, but easy

Comparison of feature Technique

Item	MCNP	MONACO
Variance Reduction	WWG (Weight window generator)	CADIS (Consistent Adjoint Driven Importance Sampling)
	for only one detector	for multi-detectors
Estimation of Error	Ten statistical checks	Plan to prepare statistical checks
Visualization of outputs	Particle display Tally plots (Graph)	Mesh tally viewer Importance map

Comparison of feature
Geometry

Item	MCNP	MONACO
Geometry	Easy/ complicated	Easy
	1)Surfaces Defined by Equations, 2)Macrobodies (BOX,RPP,SPH,RCC, HEX,REC,TRC,ELL, WED,ARB) 3)Axisymmetric Surfaces Defined by Points, 4)General Plane Defined by Three Points	SCALE Generalized Geometry Package (SGGP) (CONE, CUBOID, CYLINDER, DODECAHEDRON, ECYLINDER, ELLIPSOID, HEXPRISM, HOPPER, PARALLELEPIPED, PENTAGON, PLANE, QUADRATIC, RHEXPRISM, RHOMBOID, SPHERE, WEDGE, XCYLINDER, XPPLANE, YCYLINDER, YPPLANE, ZCYLINDER, ZPPLANE)
option	Cell, LIKE n BUT, Universe, fill, Lat, TRCL	Unit, hole, rotate, array

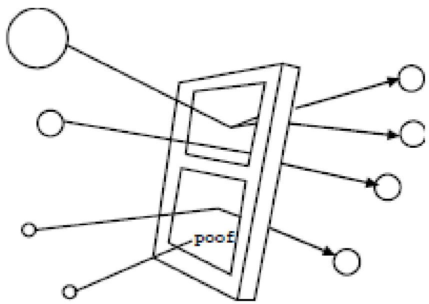
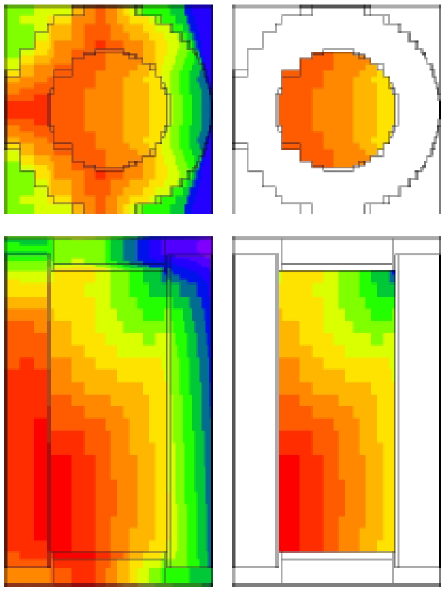
Comparison of feature
Source

Item		MCNP	MONACO
Source	No. of source region	Any(SDEF, SI, SP,SD)	One(or same material)
	Source distribution (Region)		Uniform only (plan to prepare)
	Definition	Flexible, but complicated Point, Surface, Volume	Limited, but easy Volume

Comparison of feature
Tally

Item		MCNP	MONACO
Tally	Coordinate	Cartesian or cylindrical	Cartesian only
	Dose Conversion factor	Not prepared	Prepared (ANSI standard (1991) flux-to-dose-rate factors,…)
	Definition	Flexible, but complicated Point, Ring, Surface, Volume, Mesh	Limited, but easy Point, Volume, Mesh

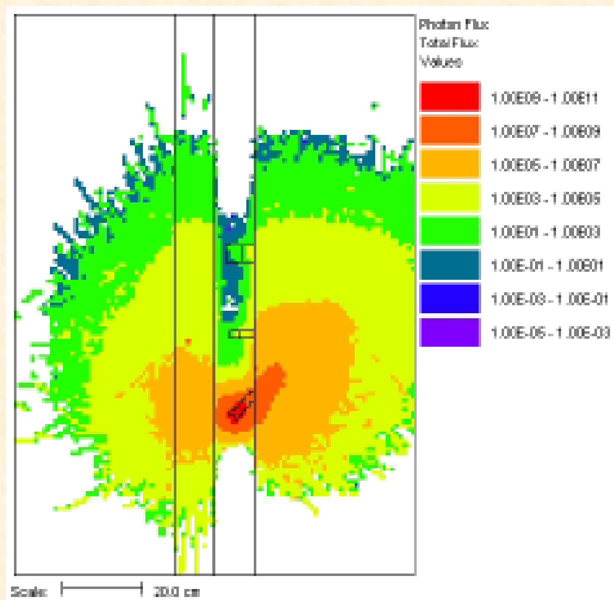
Comparison of feature
Variance Reduction

Item	MCNP	MONACO
Variance Reduction	**WWG** **(Weight window generator)** **mesh-based weight window** 	**CADIS** **(Consistent Adjoint Driven Importance Sampling)**  Target weights Source weights
	for only one detector	**for multi-detectors**

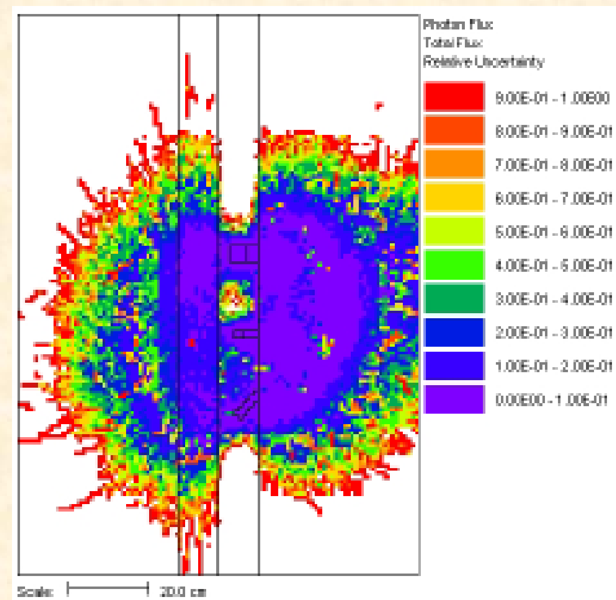
Comparison of feature
Variance Reduction

Item	MCNP	MONACO
Variance Reduction	for only one detector	for multi-detectors

FW-CADIS – for both Detectors



Total Neutron Flux

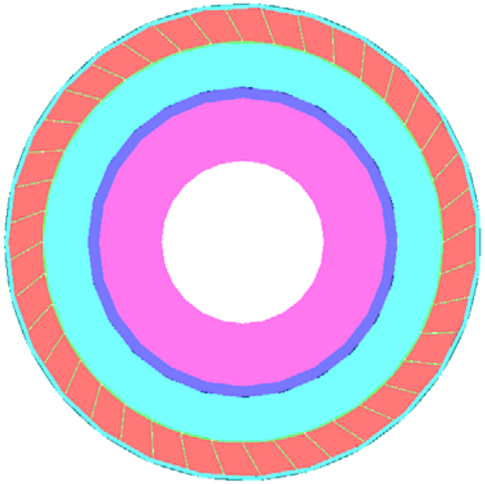


Relative Uncertainty

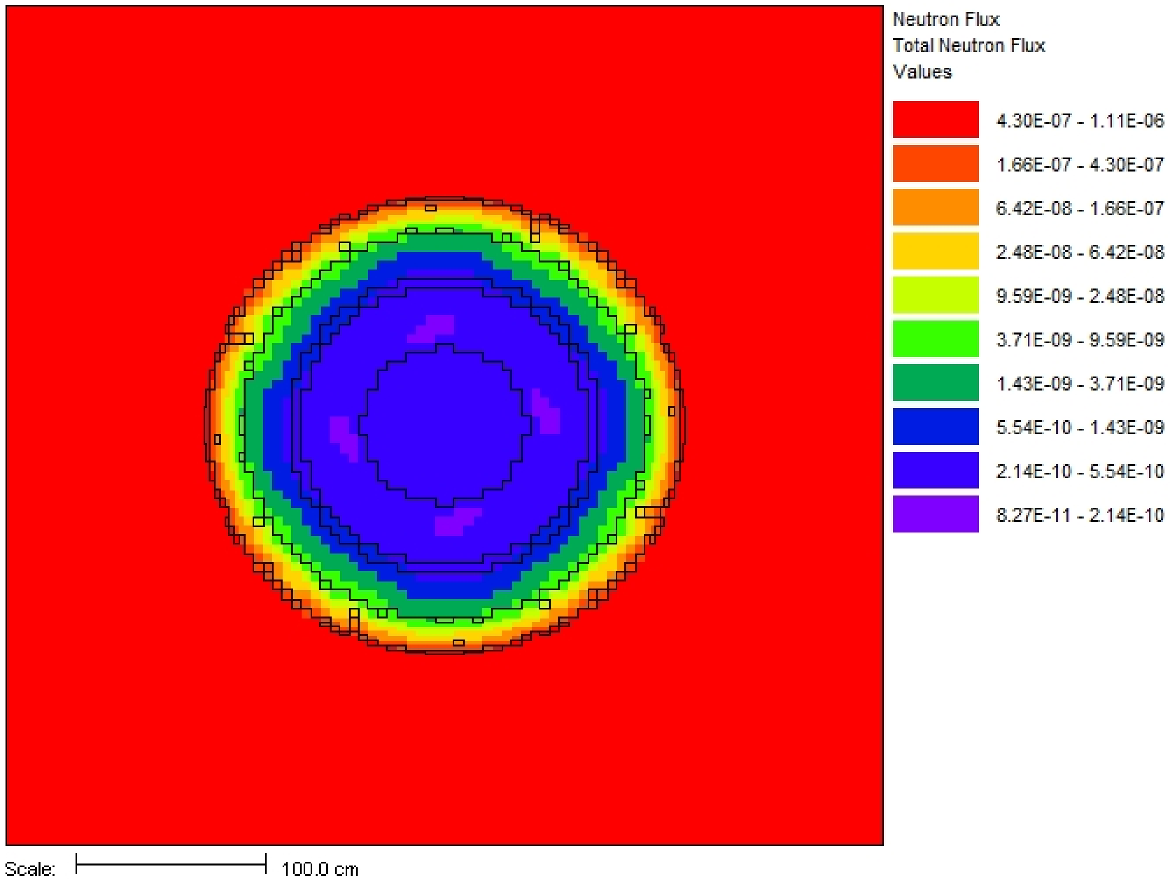
Calculation	Minutes
Forward DO	6
Adjoint DO	7
Monte Carlo	126

Results
Near 1.54×10^{3} (±0.6%)
Far 5.56×10^{1} (±0.4%)

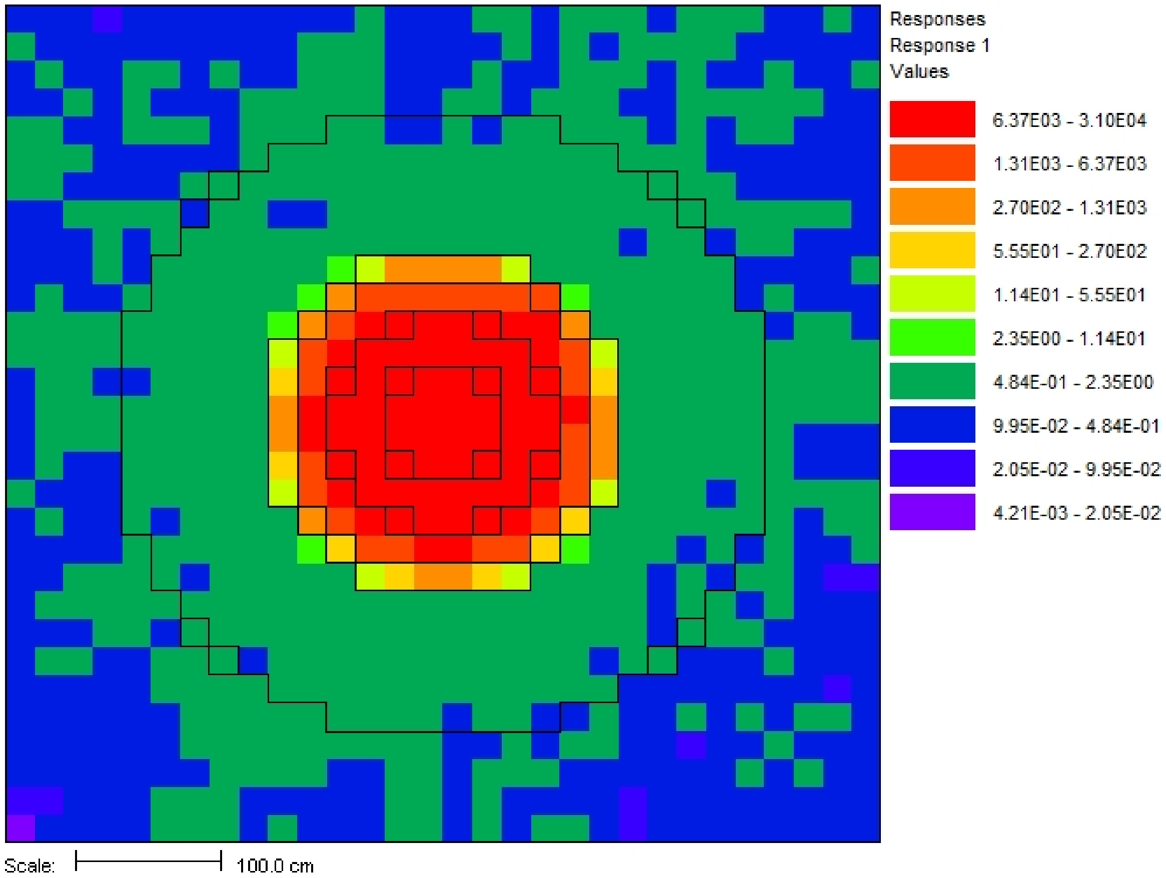
Comparison of feature
Visualization of outputs

Item	MONACO
Visualization of outputs	Input geometry 

Comparison of feature
Visualization of outputs

Item	MONACO
Visualization of outputs	**Mesh for Denovo** 

Comparison of feature
Visualization of outputs

Item	MONACO
Visualization of outputs	**Mesh tally viewer** 

Comparison of calculation

- **Model-1 : simple cask geometry**

(neutron shielding region including copper fins is homogenized)

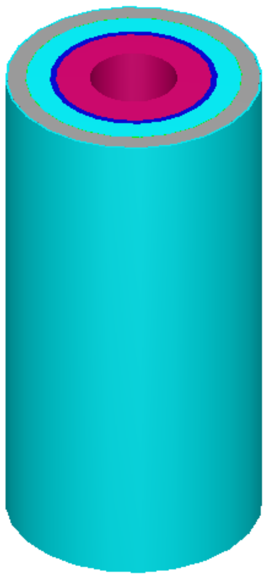
- **Model-2 : detailed cask geometry**

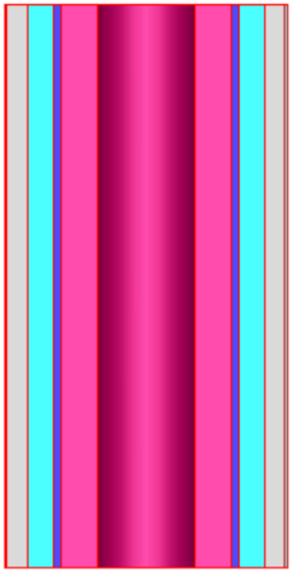
(explicitly defined copper fins in neutron shielding region)

- **Condition**
  - **Source:**
    Neutron source：Pu-239, by Watt spectra equation Intensity :1.0E9.
    FP gamma：18years cooled BWR spent fuel Intensity 1.0E16.
    Source region is assumed as ring shape in a cavity of the cask to reduce the calculation time
  - **Detector: Point detector (1m from the cask surface at axial center)**
    Large surface ring detector (cylindrical surface detector with 2m axial height at 1m from the cask surface at axial center)

for MONACO: surface detector–like volume detector is created

Model-1
(simplified model)





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Effect of setting cell importance in MCNP calculation with simplified model

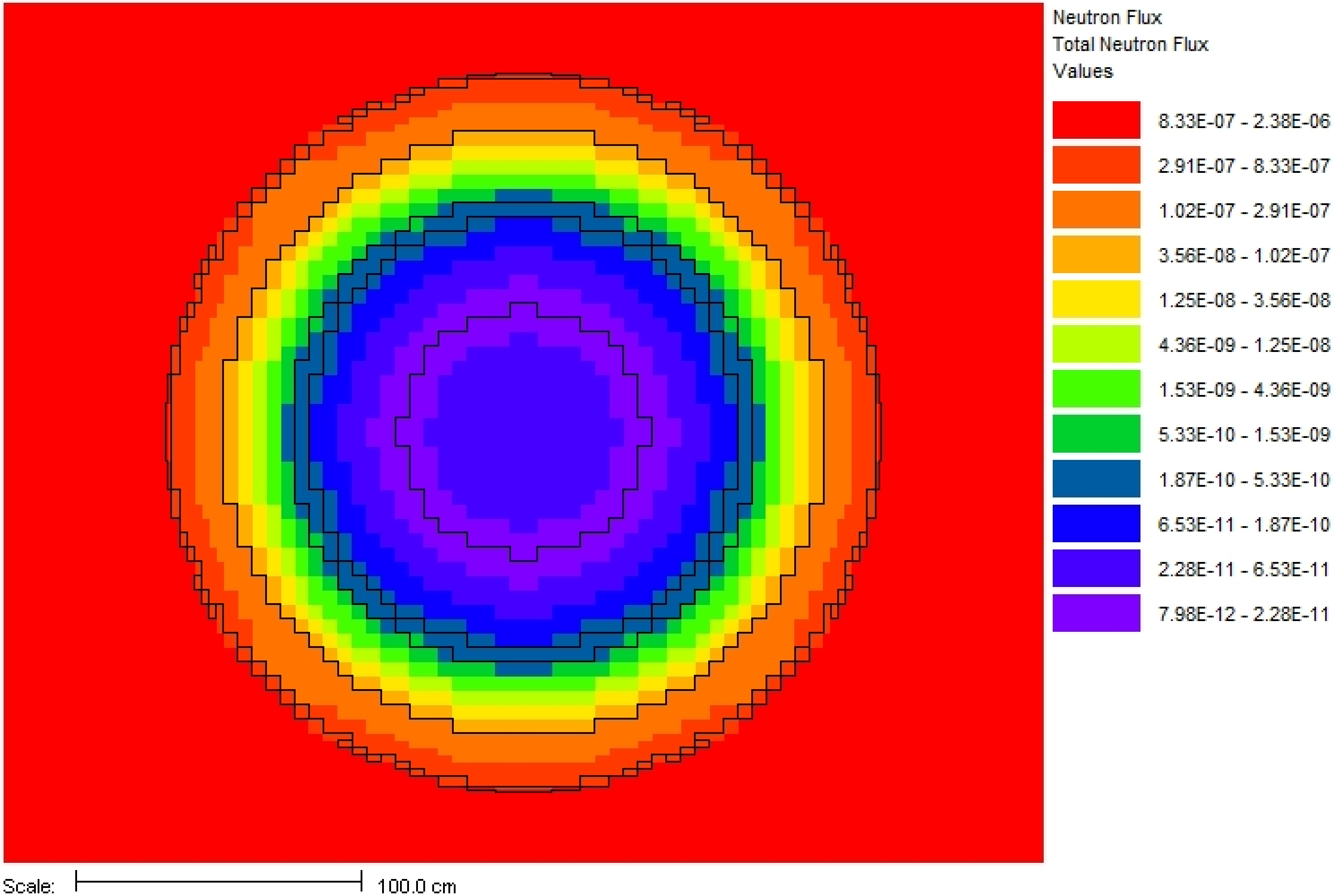
Source type	Variation of cell importance for first run	CPU time (min.)	history	Point detector		Surface Ring detector	
				Dose rate	error*)	Dose rate	error
neutron	Imp=1(all cell)	477	50000000	0.63	0.033(10/10)	0.62	0.022(10/10)
	Imp=1 to 5000	100	105428	0.58	0.038(10/10)	0.63	0.017(10/10)
	Imp=1 to 128	100	2774368	0.63	0.030(10/10)	0.63	0.017(10/10)
gamma	Imp=1 to 5000	500	368253756	6.65	0.051(8/10)	6.76	0.023(9/10)
	(longer time)	-	4579748533	7.16	0.018(10/10)	6.93	0.008(10/10)

*) The number in the brackets shows the passed results of 10 statistical checks.

Effect of setting cross section/SN in MONACO calculation with simplified model

Source type	Library and number of mesh		CPU time*) (min.)	history	Point detector		Surface Ring detector	
					Dose rate	Uncertainty	Dose rate	Uncertainty
neutron	Reference case	27n+19g	49(+11)	6000x100	0.97	0.015	0.97	0.006
		P1S4 (200n+47g)	42(+72)		0.59	0.020	0.59	0.009
		P3S8 (200n+47g)	44(+145)		0.58	0.021	0.59	0.009
gamma	Reference case	27n+19g	169(+5)	250000x100	6.78	0.011	6.70	0.004
		P1S4 (200n+47g)	229(+21)		6.73	0.011	6.67	0.004
		P3S8 (200n+47g)	205(+28)		6.53	0.011	6.69	0.005

Effect of mesh size for Denovo (Number of mesh:100000)



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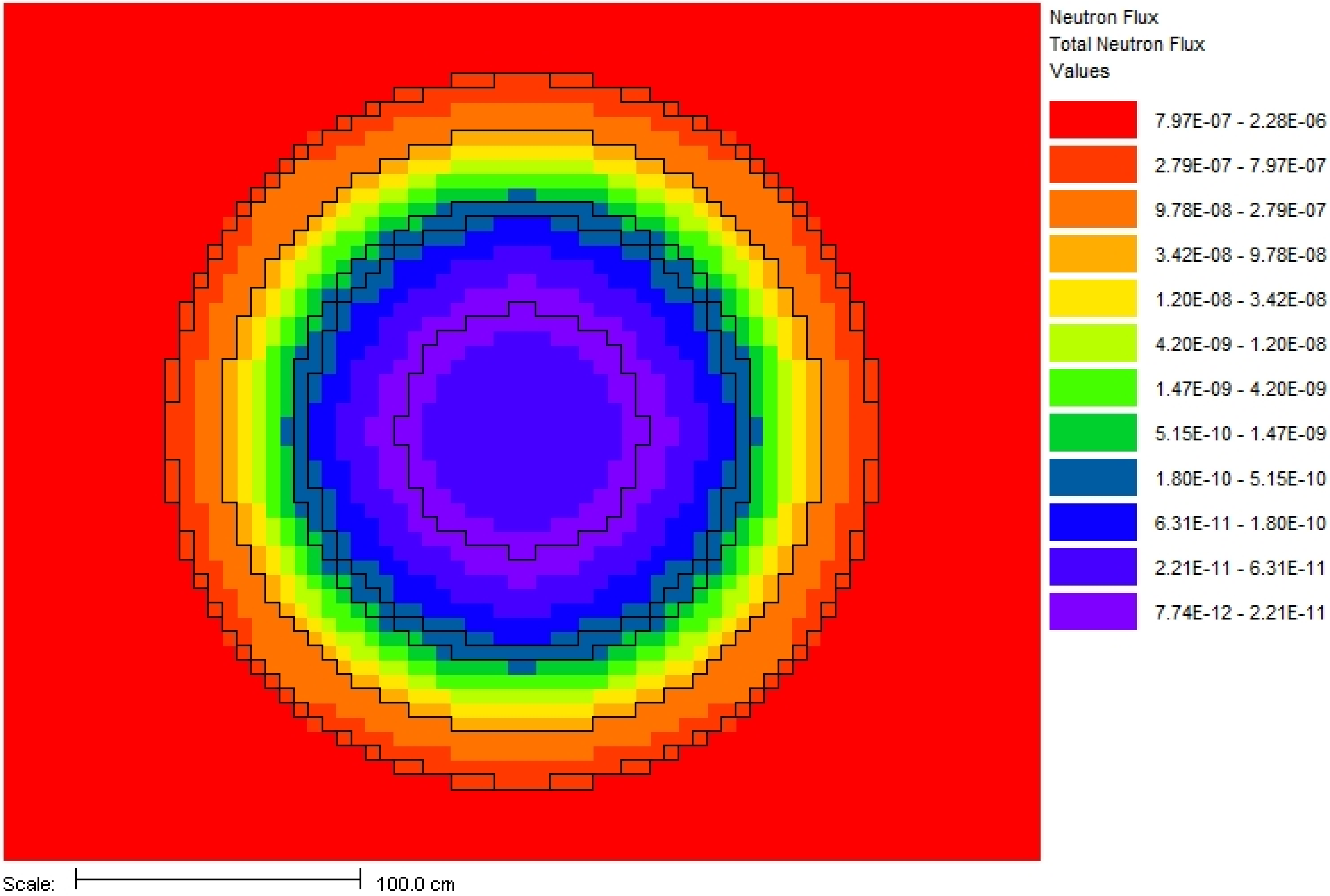
Effect of mesh size for Denovo (Uniform mesh:73000)



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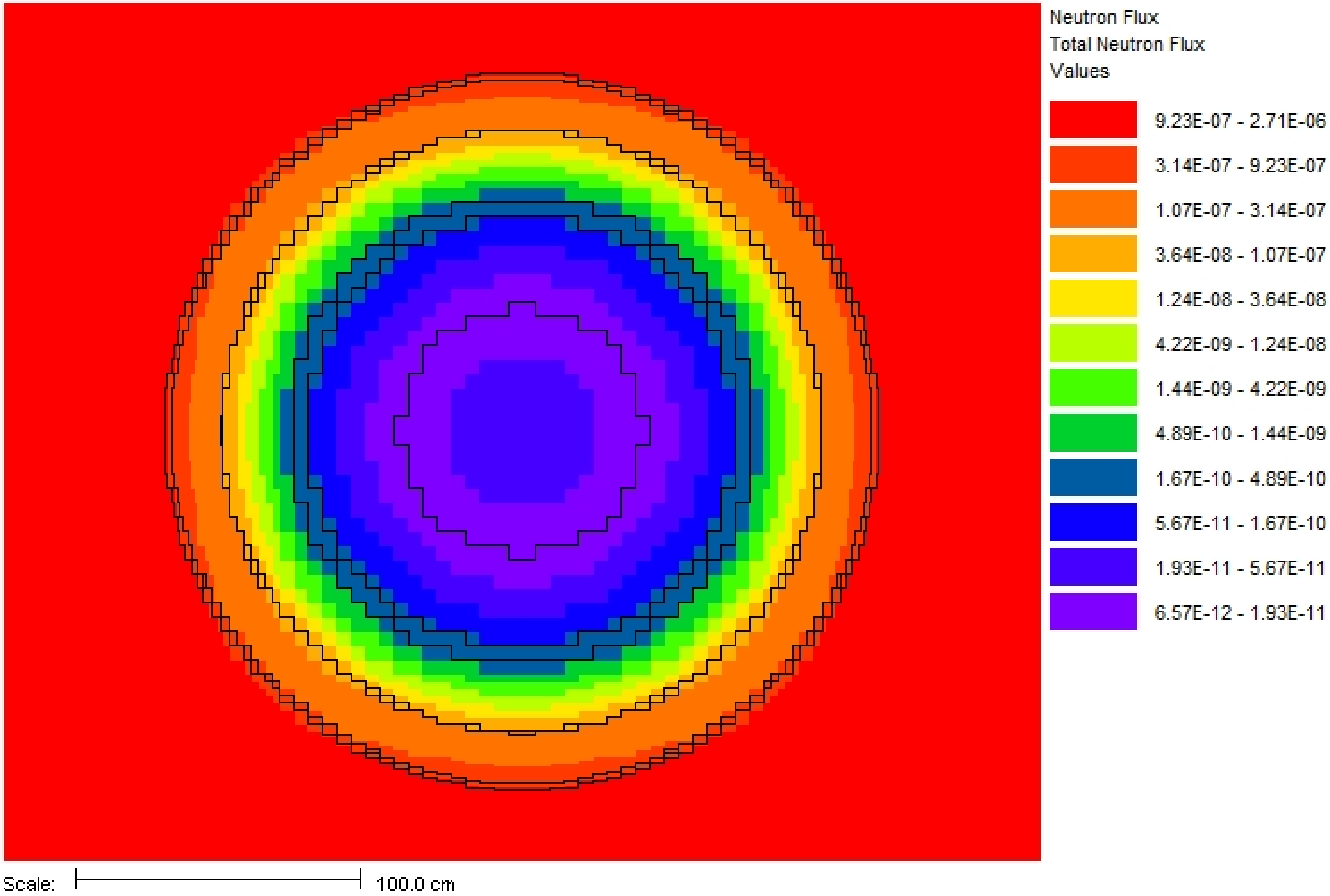
Effect of mesh size for Denovo (Large number of mesh :179000)



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Effect of setting mesh in MONACO calculation with simplified model

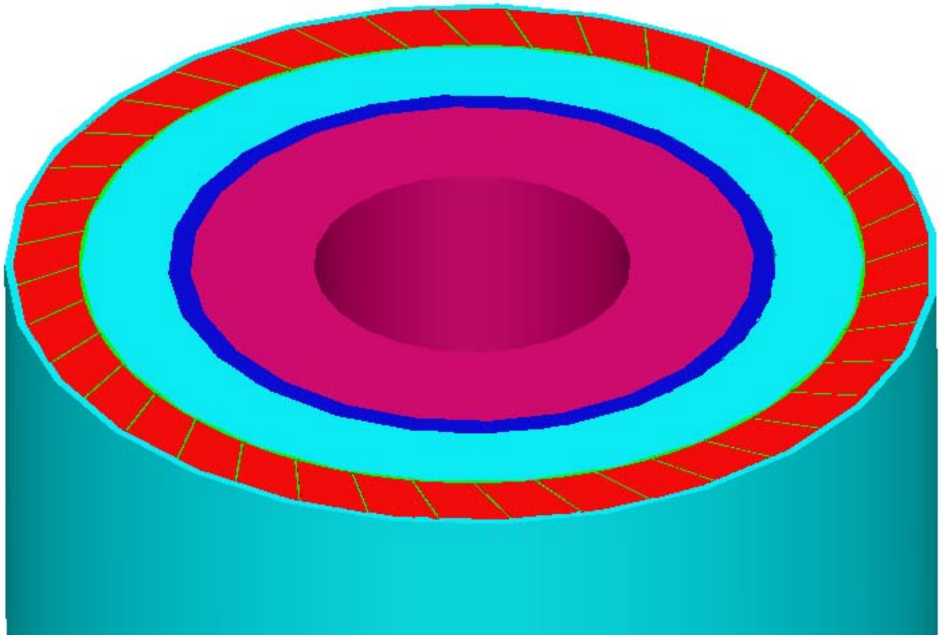
Source type	Library and number of mesh	CPU time*) (min.)	history	Point detector		Surface Ring detector	
				Dose rate	Uncertainty	Dose rate	Uncertainty
neutron	200n+47g	42(+72)	6000x100	0.59	0.020	0.59	0.009
	Uniform mesh	46(+53)		0.63	0.020	0.60	0.010
	Large number of mesh	39(+110)		0.61	0.019	0.60	0.008
gamma	200n+47g	229(+21)	250000x100	6.73	0.011	6.67	0.004
	Uniform mesh	235(+19)		6.70	0.011	6.65	0.004
	Large number of mesh	233(+31)		6.76	0.010	6.73	0.004

Comparison of calculation

- Comparison of MCNP and MONACO with simplified model

Source type	item	MCNP		MONACO	
		Dose rate	Error	Dose rate	Uncertainty
Neutron	Point detector	0.63	0.030	0.59	0.020
	Surface Ring detector	0.63	0.017	0.59	0.011
	CPU time	100		42(+72)	
	No. of Calculation	1		1	
Gamma	Point detector	6.65	0.051	6.73	0.011
	Surface Ring detector	6.76	0.023	6.67	0.004
	CPU time	500(1100)		229(+21)	
	No. of Calculation	2+1		1	

Model-2
(fin detailed model)



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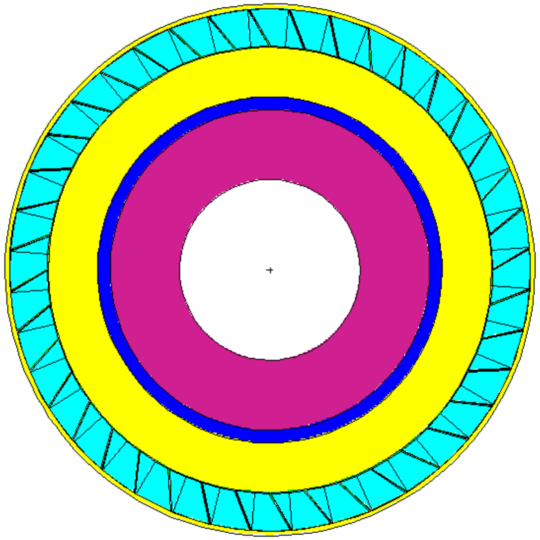
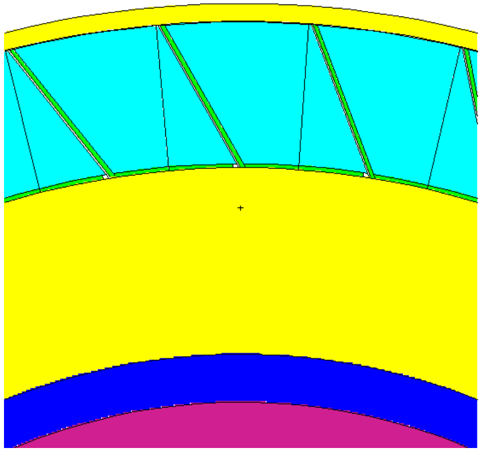
Model-2
(fin detailed model)





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Comparison of calculation

- **Comparison of MCNP and MONACO with detailed model**

Source type	item	MCNP		MONACO	
		Dose rate	error	Dose rate	uncertainty
neutron	Point detector	0.66	0.014(8/10)	0.64	0.044
	Surface Ring detector	0.66	0.008(8/10)	0.62	0.019
	CPU time	100(+100)		600(+67)	
	history	19133462		6000x26	
	No. of Calculation	2		1	
gamma	Point detector	6.95	0.042(9/10)	6.52	0.032
	Surface Ring detector	7.01	0.015(10/10)	6.82	0.012
	CPU time	1500(+600)		2030(+15)	
	history	641118619		100000x31	
	No. of Calculation	2+1		1	

Conclusion

- **MCNP and MONACO are compared**
- **Both codes are good enough to calculate dose rate around casks. (except neutron calculation by MONACO with 27n+19g library)**

- **Neutron : reliability and the total calculation time are reasonable enough to apply for shielding calculations of casks.**
- **Gamma : considerable longer calculation time are necessary to obtain the reliable gamma dose rate.**

  : variance reduction method CADIS in MAVRIC seems more powerful than Weight Window Generator in MCNP.

- **From the viewpoint of Monte Carlo code user,**

  the best mixture of MCNP and MONACO is preferable.