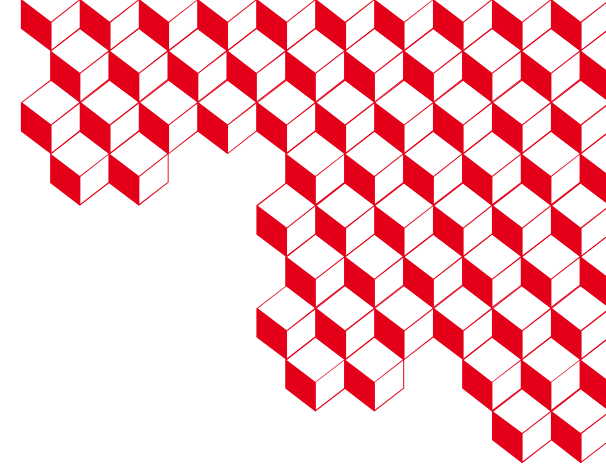




Adult and pediatric organ dose calculations with Tripoli-4 Monte-Carlo code

Johanna Ngai, Grenoble-INP PHELMMA en génie énergétique et nucléaire

INTERNSHIP : DM2S /SERMA CEA Paris-saclay from 16/04/2025 to 10/09/2025

SUPERVISORS : Yi-Kang Lee et François-Xavier Hugot

SUMMARY

1. Context and Objectives

2.Challenges with Tripoli4.12

3.First dosimetry results

4.Next steps and conclusion



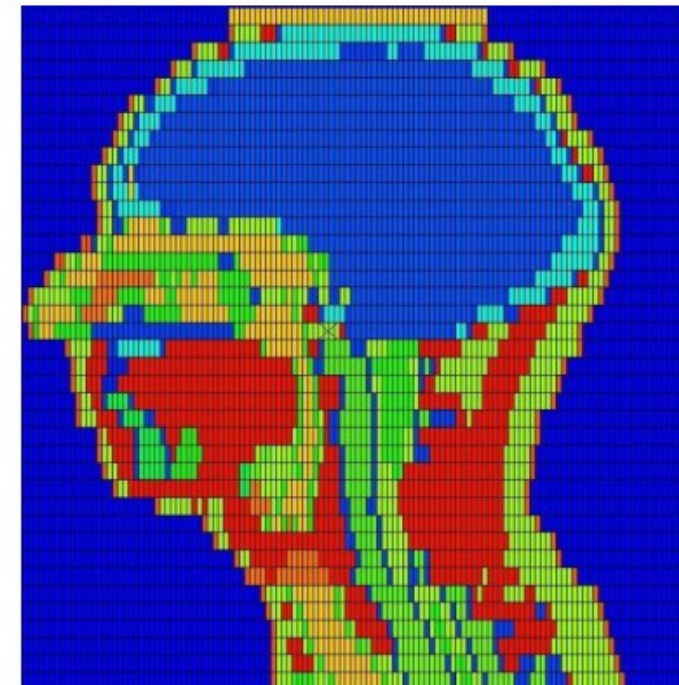
1. Context and objectives

Ref :

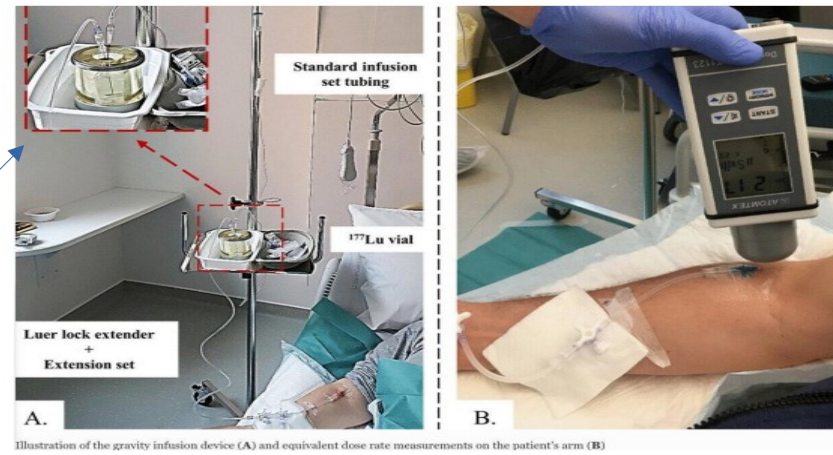
(1) Tripoli-4: F.-X.Hugot et al.,EPJ Nuclear Sci.Technol 10,17 (2024)

(2) T4G : Y.-K.Lee,F.-X.Hugot,Proc of ICONE 31,31st Int.Conf. On Nucl. Eng.,Prague,Czech Republic (2024)

(3) ICRP 110 : International Commission on Radiological Protection,ICRP publication 110 . Elsevier 2009

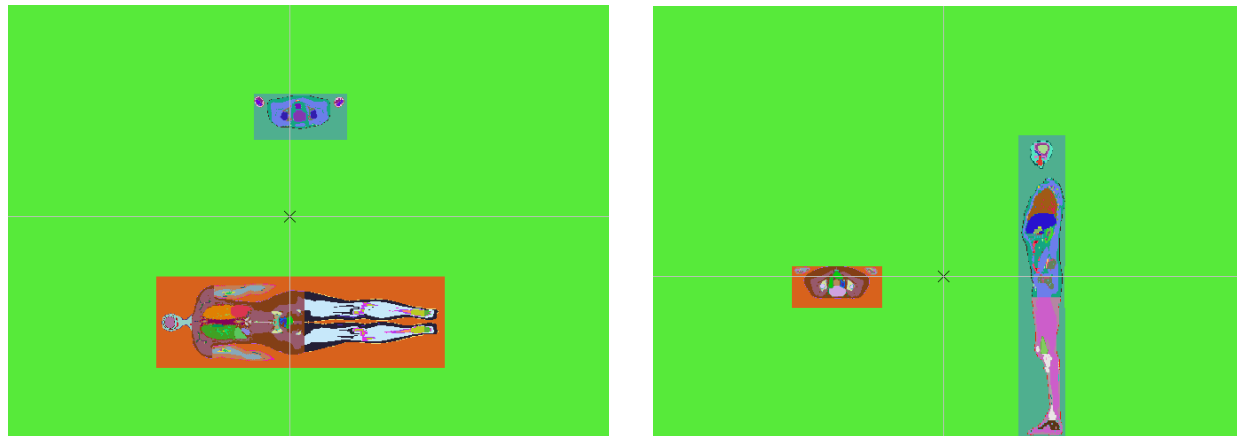


a) External dose rates from nuclear medicine patients (I-131, Y-90, Lu-177)

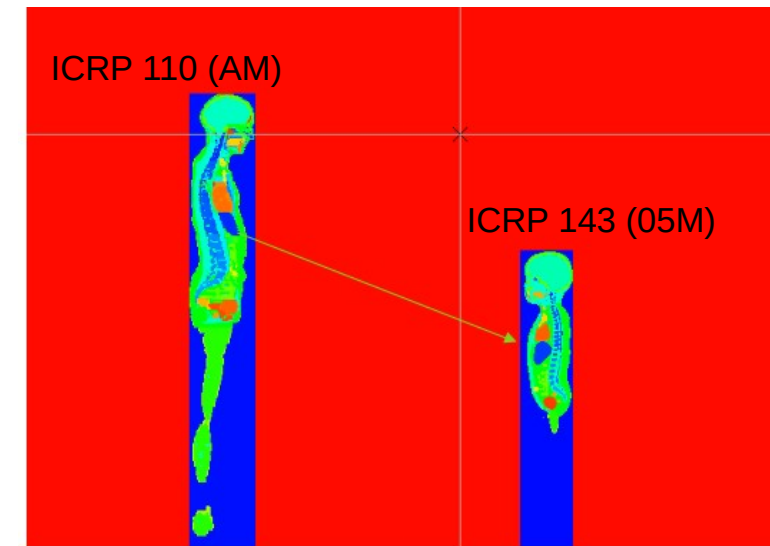


Ref: EJNMMI Phys 9 (2022) article 33
J. Applied Clinical Medical Physics 23 (2022) e13713

b) How far and for how long should the patient stay away from medical staff and their own relatives



Phantom voxels: AM and AF (Tripoli-4.12+dev) : X-Y view (left image) and Y-Z view (right image)



Voxel phantoms : AM and O5M (Tripoli-4.12+dev)
Y-Z view

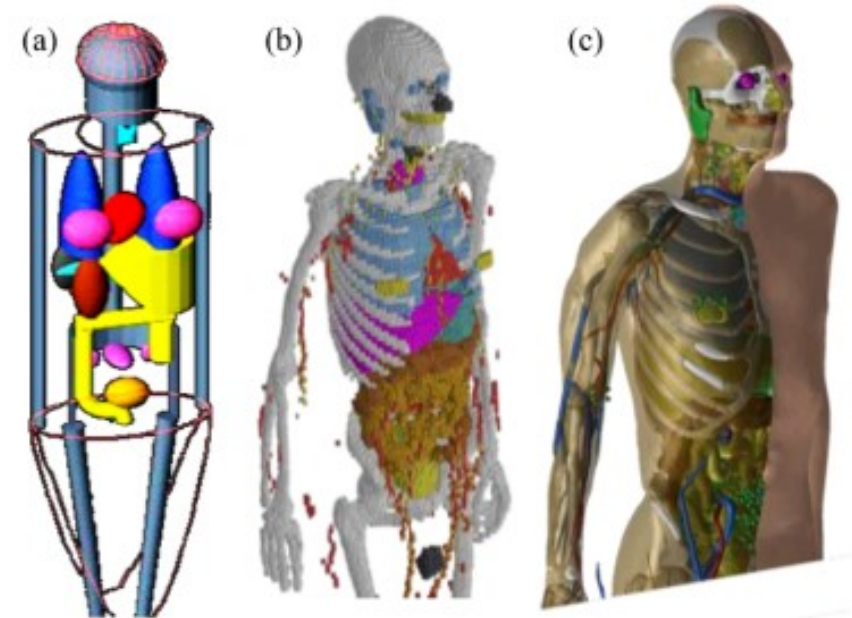
Ref :

EURADOS : European Radiation Dosimetry group (WG6 and WG13)

ICRP 143 : International Commission on Radiological Protection, ICRP publication 143 . SAGE 2020

c) Can Monte-Carlo codes be efficient/fast enough to be used by medical physicists and which phantom geometry model should be used ?

d) Is there a possibility to improve TRIPOLI-4 lattice option ?



3 generations of phantoms : (a) MIRD phantoms , (b) Voxel phantoms, (c) mesh phantoms

Ref :

(a) MIRD : committee on Medical Internal Radiation Dose

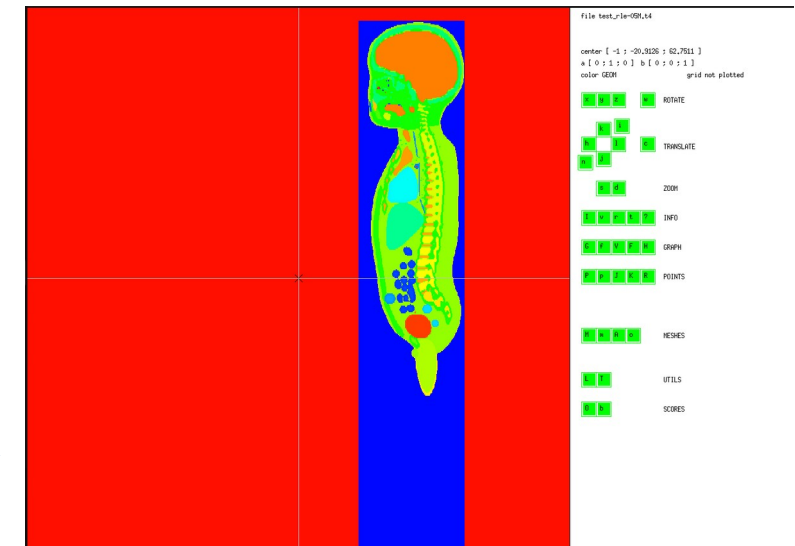
(b) ICRP 110 : International Commission on Radiological Protection, ICRP publication 110 . Elsevier 2009

(c) ICRP 145 : ICRP, 2020. Adult mesh-type reference computational phantoms. ICRP Publication 145. Ann. ICRP 49(3)



2.Challenges with Tripoli 4.12

T4G [11] run time (sec)*	Old version [2]		New route [see Section 2.1 and Table II (1) Co-60]			
	Single ICRP 110 Phantom				Two phantoms	
	AM	AF	AM	AF	AM-AM	AM-AF
Preprocess	3.4	6.9	< 1.0			
Initialization	11.6	33.9	71.7	214.3	145.7	282.8
Display each 2D view	64.9 – 273.5		0.1 – 0.5			
* Single thread CPU runtime benchmark measured with the Intel Xeon Silver 4114 @ 2.20GHz						



05M (tripoli-4.12+dev)

05M : 05 years old Male

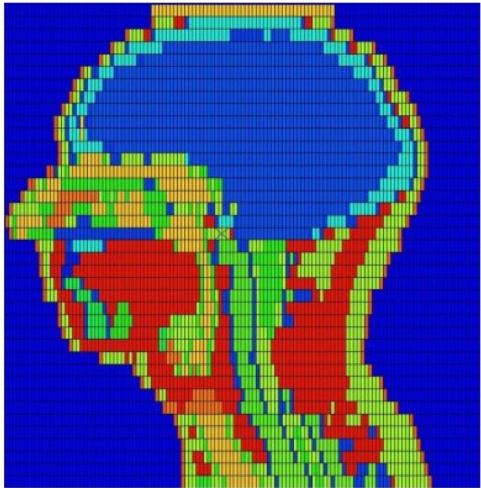
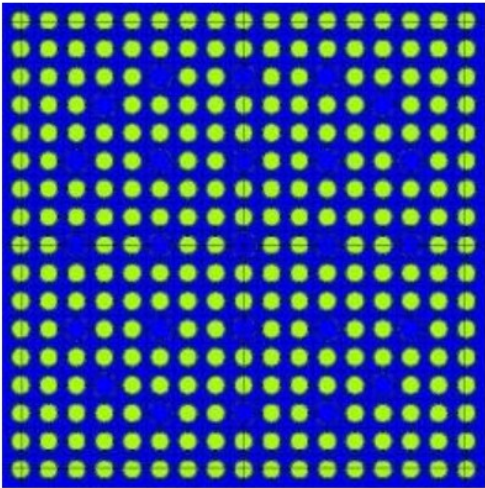
◆ Memory (RAM):

	Adult Male (AM)	Adult Female (AF)	05 years old Male (05M)
Number of voxels x-y-z	254*127*222	299*137*348	419*230*572
Total number of voxels	7161276 (7 million)	14255124 (14 million)	55123640 (55 million)
Data file size (MB)	28,8	57,4	145,6
RES (GB)	1,3	2,4	8,2
VIRT(GB)	~1,6	~2,7	~8,7

My pc has 40 processors and RAM~65Gbytes

Trying to run parallel calculations of AF and 05M cost ~11 Gbytes

In comparison :



PWR fuel assembly model ⇔ ICRP 110 AM voxel phantom

(17 x 17 x 1)(254 x 127 x 222)

ICRP : International Commissson on Radiological protection (publications 110 and 143)



3.First dosimetry results

◆ Photon point source

Target organs	AM (Gy)	AF (Gy)	05M (Gy)	Ratio AF/AM	Ratio AF/AM (Reference)	Ratio 05M/AM	Ratio 05M/AF
Brain	2,82E-04	3,30E-04	3,43E-04	1,17	1,19	1,22	1,04
Liver	3,91E-04	4,28E-04	4,27E-04	1,09	1,11	1,09	1,00
Skin	2,52E-04	2,59E-04	2,78E-04	1,03	1,05	1,10	1,07

Table 1 :Tripoli 4.12 calculated organ doses for adult male,adult female and 05 year old male

Organ/Tissue	dose absorbed (Gy)	Sigma (%)	(*) Reference organ absorbed dose for comparison (Gy)	Ratio Tripoli-4(2024)/MCNPX 2022
	with Tripoli-4.12			
colon	4,243E-04	7,98E-01	4,09E-04	1,0375
breast	5,367E-04	2,89E+00	5,36E-04	1,0013
lung	3,868E-04	8,23E-01	3,84E-04	1,0072
stomach	4,341E-04	8,38E-01	4,30E-04	1,0096
RBM	3,74E-04	3,54E+00	3,26E-04	1,1472
Gonads	3,955E-04	1,99E+00	3,91E-04	1,0116
oesophagus	3,667E-04	1,76E+00	3,69E-04	0,9936
liver	3,911E-04	8,44E-01	3,86E-04	1,0132
brain	2,824E-04	1,21E+00	2,81E-04	1,0050
skin	2,621E-04	5,93E-01	2,60E-04	1,0079

Table 2 :Tripoli 4.12 calculated organ doses for adult male (some of the organs involved in the calculation of effective dose)

(a) : ICRP 116 method with dose response functions

* : C. HUET et al., Radiation Measurements, Vol. 150, Jan 2022, 106695

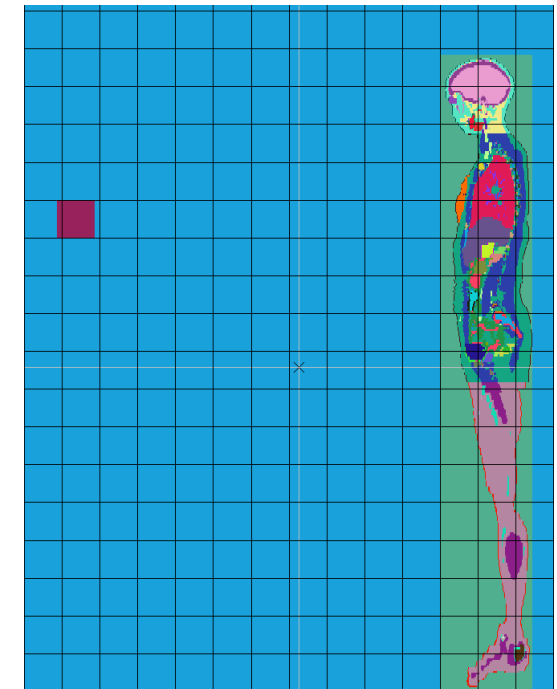
Ref : Y.-K. LEE, J. Nucl. Eng. And Radiation Science, 6(4): 041105, 2020

Johanna Ngai

L.A.R.D 2025

01/07/2025

10



AF and Co-60 point source at 1m from the chest

◆ Contaminated ground :

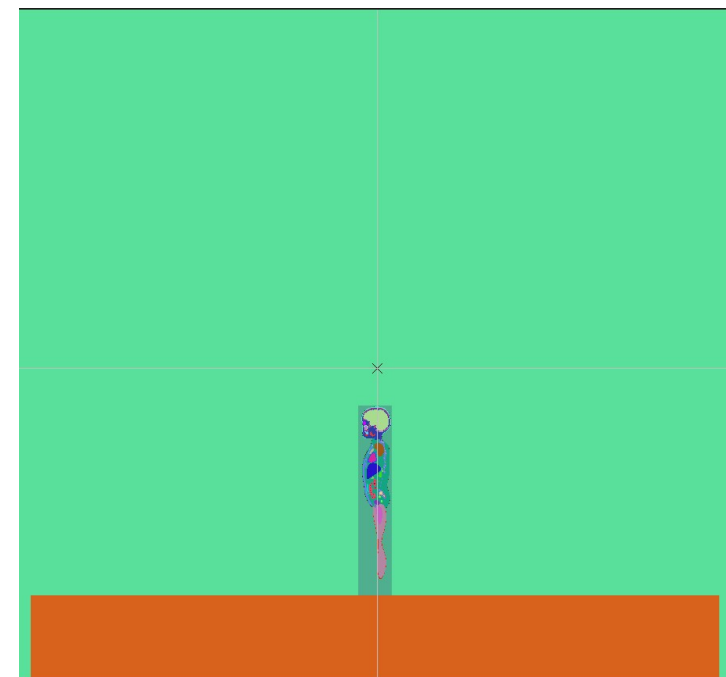
Am 241 surface disc source to simulate ground contamination for environmental dosimetry

Organ	absorbed dose rate (Gy/s)	sigma(%)	Reference dose rate(Gy/s)	Ratio Tripoli-4.12/Tripoli-4.10
BRAIN	2,55E-08	2,18E+00	2,53E-08	1,009
LUNG	3,69E-08	1,85E+00	3,60E-08	1,024
SKIN	1,61E-07	4,60E-01	1,58E-07	1,018
Breast	5,72E-08	2,82E+00	5,65E-08	1,013

Table 1 : Tripoli 4.12 calculated organ dose rate for AM compared to the reference dose rates computed with Tripoli-4.10

Organ	AM dose rate (Gy/s)	05M dose rate (Gy/s)	Sigma(%) for 05M	Ratio 05M/AM
BRAIN	2,55E-08	8,85E-08	1,22E+00	3,47
LIVER	4,95E-08	1,42E-07	1,39E+00	2,86
LUNG	3,69E-08	1,20E-07	1,96E+00	3,25
SKIN	1,61E-07	2,68E-07	9,46E-01	1,67

Table 2 : comparison of Absorbed dose between adult male and 05 year old male



05M standing at the center of a ground contaminated by Am 241(Tripoli 4.12+dev)



4. Next steps and conclusion

1. Correctly implement the ICRP 116 method for the calculations of the RBM and endosteum RBM is the Red Bone Marrow and endosteum is a 50-μm-thick layer covering the surface of the bone trabeculae.

$$D(r_T, x) = \int_E \Phi(E, r_S, x) R(r_T \leftarrow r_S, x, E) dE \quad (4)$$

where $D(r_T, x)$ is the absorbed dose to tissue r_T in bone site x , $\Phi(E, r_S, x)$ is the energy dependent photon fluence through source region r_S in bone site x , and $R(r_T \leftarrow r_S, x, E)$ is the bone-specific energy dependent dose response function.

In this equation r_T is either active marrow or endosteum, r_S is either spongiosa or medullary marrow

2. Perform the calculations of effective dose of the whole body and the gender-averaged effective dose

$$E = \sum w_T \left[\frac{H_T^M + H_T^F}{2} \right]$$

H_T : Equivalent dose is the dose in a tissue or an organ (Sv)
 w_T : Tissue weighting factor
 E : Effective dose in Sv

(2.10)

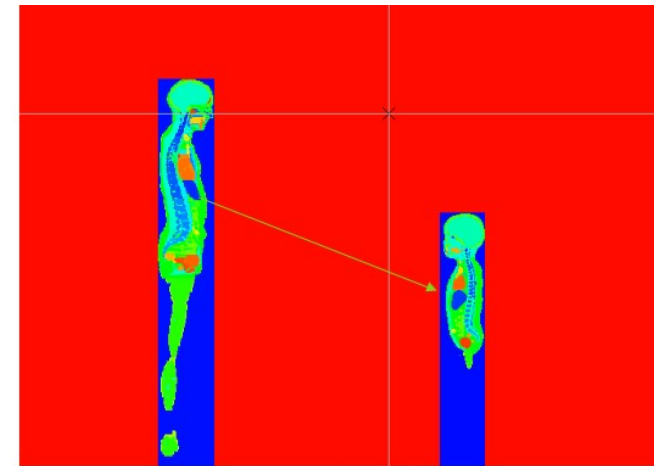
Ref :

(2.10) : ICRP 116 :International Commission on Radiological Protection,ICRP publication 116 . Elsevier 2010

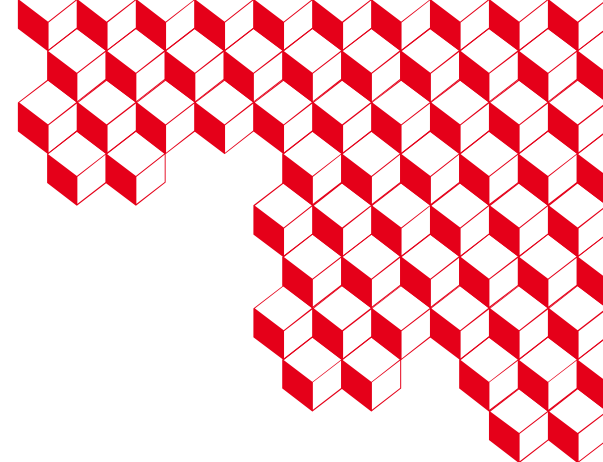
(4) :Zankl et al., Radiation Measurements, Vol. 146 , Aug. 2021, 106611

3.Repeat these calculations for paediatric phantoms after verification of their correction representation (composition/geometry)

4. Perform two-phantoms simulations.



*Voxel phantoms : AM and O5M (Tripoli-4.12+dev)
Y-Z view*



Thank you for your attention !

CEA SACLAY
91191 Gif-sur-Yvette Cedex
France