Features of PHITS3.27

PHITS development team, Apr. 2023

Number of PHITS users since 2019

Top 10 countries

Country	#users
Japan	2317
Indonesia	302
United States	224
Philippines	179
South Korea	157
France	109
Malaysia	102
Argentina	98
China	96
Myanmar	90
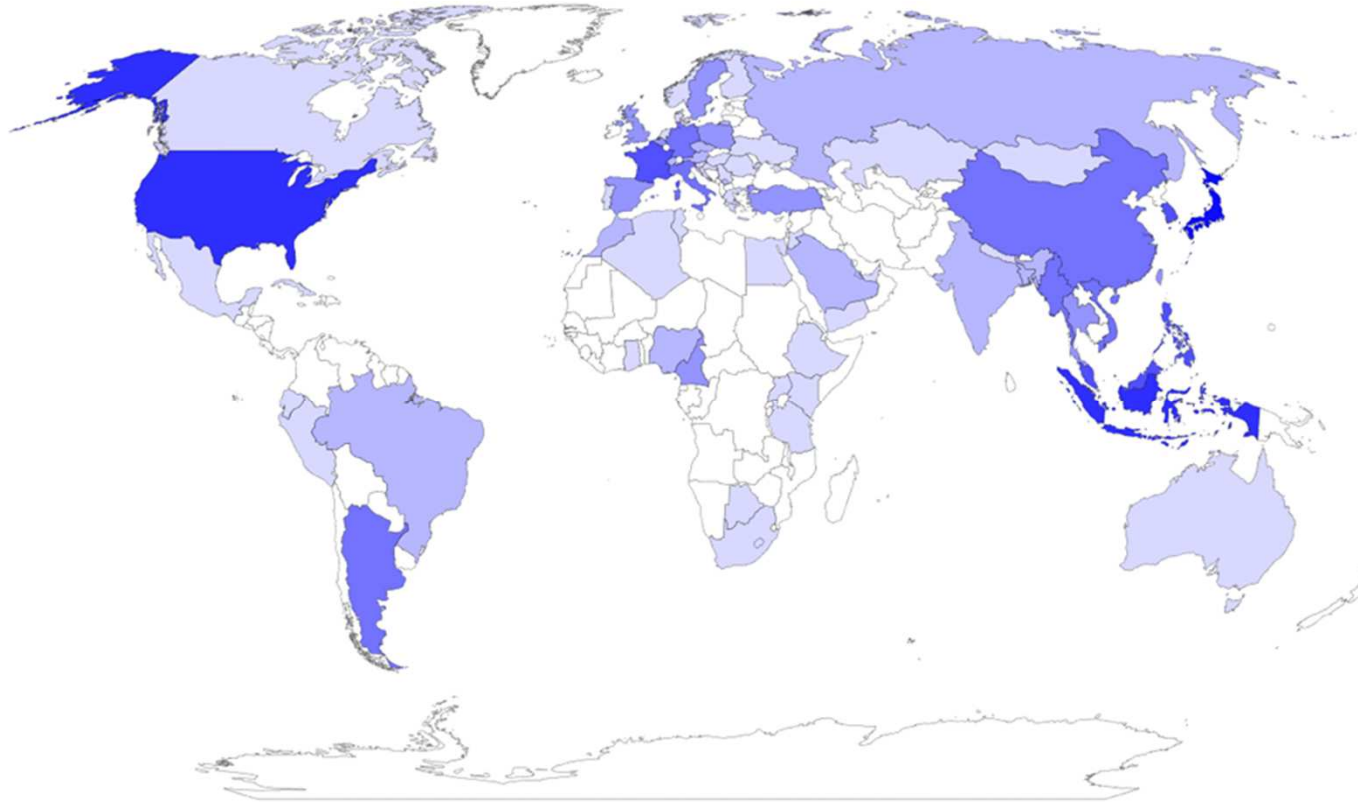
Number of PHITS users in each country since 2019*

*@03/22/2023, based on the location of users' affiliation

4,490 new users from 68 countries in four years!

https://phits.jaea.go.jp/usermap/PHITS_map_userbase.html

Map of Models Recommended to Use in PHITS

Neutron	Proton, Pion (other hadrons)	Nucleus		Muon	e⁻ / e⁺	Photon	
1 TeV	1 TeV/u						1 TeV
Intra-nuclear cascade (JAM) + Evaporation (GEM) 3.0 GeV		JAMQMD + GEM		Virtual Photo-Nuclear JAM/ JQMD + GEM 200 MeV	EGS5 or **ETS	EGS5 or EPDL97	Photo-Nuclear JAM/ JQMD + GEM + JENDL + NRF
Intra-nuclear cascade (INCL4.6) + Evaporation (GEM) 200 MeV		d t ³He α	Quantum Molecular Dynamics (JQMD) + GEM 10 MeV/u				
20 MeV	*JENDL-4.0/HE			ATIMA + Original			
Nuclear Data Library (JENDL-4.0) + (EGM) 0.01 meV	1 MeV		Energy loss		1 keV	1 keV	
	1 keV ATIMA or **KURBUC/ITSART						
	*Only for facility design **Only for microscopic simulation			Muonic atom + Capture	**ETS 1 meV		

Energy: High ↑ ↓ Low

There is no significant change since version 3.27

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Major Upgraded Features in ver. 3.31

Since version 3.27

✓ Model for E-M de-excitation (EBITEM) has been improved

✓ A new function to use character variables has been implemented[*1)]

✓ A new parameter "samepage" has been introduced[*1)]

✓ A new microdosimetric function has been developed in the [t-sed] tally

✓ Instruction for defining user-own "interactions" and "particles" has been prepared and released via github

✓ ICRP voxel and mesh reference adult phantoms have been included[*2)]

✓ RI source function has become applicable to self-fission neutron sources[*3)]

✓ Usage of most memory has been changed from static to dynamic allocation[*3)]

✓ A new option to output the cross sections contained in nuclear data library and stopping power has been implemented in "icntl=1" mode[*3)]

*1) Under support of NAIS Inc.
*2) Under support of ICRP and Hanyang University
*3) Under support of RIST

Major Upgraded Features in ver. 3.31

Since version 3.27

- ✓ ITSART has been upgraded to be applicable to heavy ions and be feasible to treat excitations

- ✓ A new option of [t-cross] and [t-product] to output the results as a function of LET has been implemented[*1)]

- ✓ Anatally function becomes feasible to analyze the results from different tallies[*1)]

- ✓ [t-produce] becomes feasible to score secondary particles generated using nuclear data libraries[*1)]

- ✓ Several bugs in [t-point] have been fixed

- ✓ A new function to detect geometry errors in PHIG-3D has been implemented[*2)]

*1) Under support CCSE of JAEA
*2) Under support of National Maritime Research Institute

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E-M deexcitation model (EBITEM) upgrade

EBITEM : Model for E-M (mainly gamma)deexcitation

How to use: Activated by |igamma| $\geqq$ 2 , which is default.
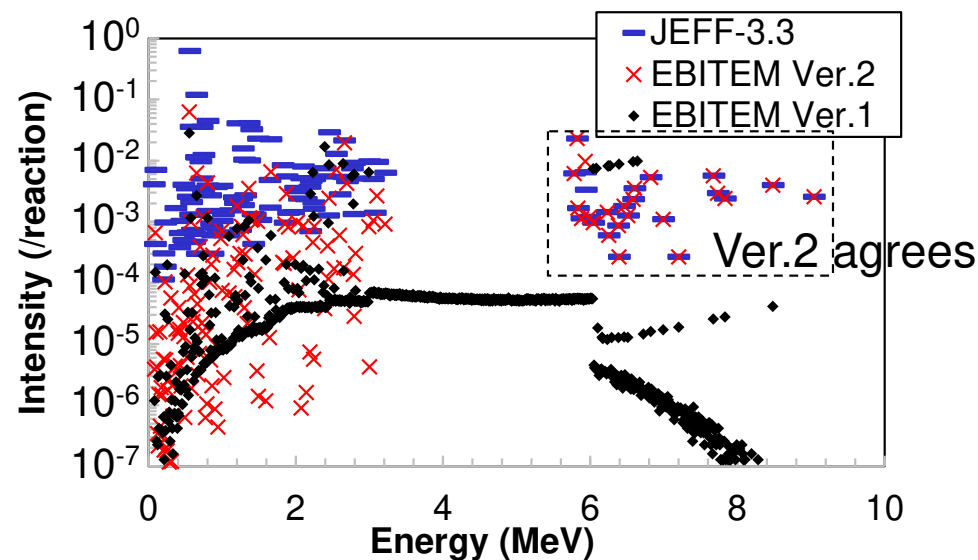
Old model (EBITEM Ver.1)

New model(EBITEM Ver. 2)

- Structure data is ENSDF in 2013 $\longrightarrow$
- Use neutron capture γ-rays literature data for H-Ge, Gd, Ta、W $\longrightarrow$
- Gamma-decay only $\longrightarrow$

- Use RIPL-3
- Cover all nuclei by Evaluated Gamma Activation File(EGAF)
- Consider internal conversion, Auger e⁻, and fluorescent X-rays
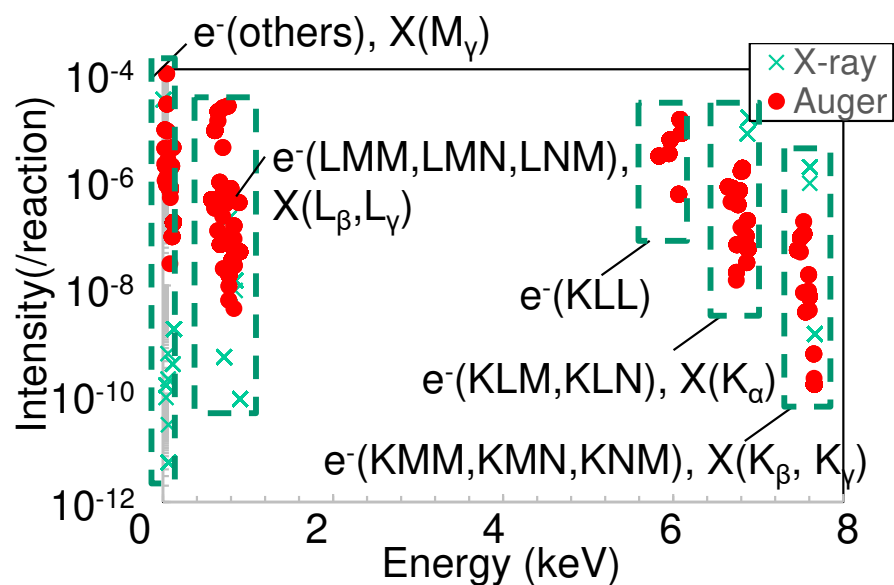
X-rays and Auger e⁻ from ⁵⁹Co-59(n,γ)

^{113}Cd(n,γ) γ-ray spectrum

User-defined character

onion.inp in lec03

```
[M a t e r i a l]
mat[1]   Au 1
set:%Au%[1 -19.32]
mat[2]   H 2  O 1
set:%H2O%[2 -1.0]
mat[3]   Cu 1
set:%Cu%[3 -8.93]
mat[5]   C 2  H 4
set:%C2H4%[5 -0.9]
mat[6]   N 8  O 2
set:%Air%[6 -1.20e-3]
...

 [C e l l]
 100  -1      10
 101  %Au%    -11
 102  %H2O%    11  -12
 103  %Cu%     12  -13
 104  %H2O%    13  -14
 105  %C2H4%   14  -15
 106  %Air%    15  -10
```

How to use

- Character variable can be set as
  set:%Variable_Name%[character]

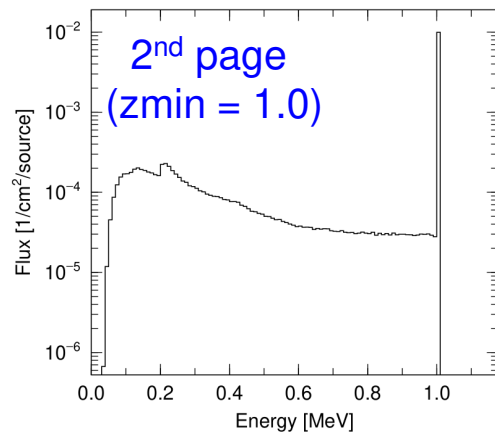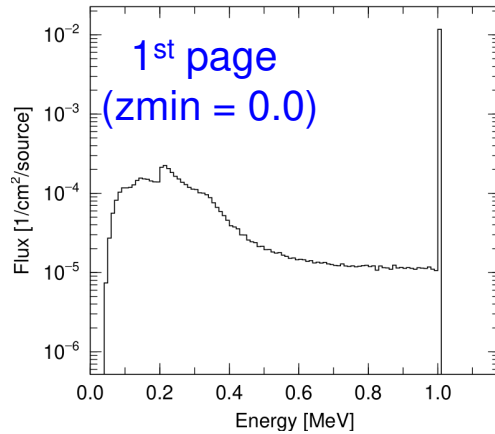- LARGE and small characters are distinguished (Case Sensitive!)

Important Notice

- PHIG-3D is not compatible with this function

- Input data after converting the character variables are generated in a rewrite-file named *_rwt.inp

- You can skip to generate *_rwt.inp by adding "$RWT=0" before the 1st section for reducing the computational time (effective for larger input file)

- You can generate *_rwt.inp without performing particle transport simulation by adding "$RWT=3"

  → send *_rwt.inp to PHIG-3D

"samepage" parameter

samepage = part
(default, before ver. 3.30)

1st page
(zmin = 0.0)

2nd page
(zmin = 1.0)

page-continue up to
the final depth region…

samepage = z

no. = 1, part = photon, ir = 1

vol = 7.8540E+01 [cm³]
rmin = 0.0000E+00 [cm]
rmax = 5.0000E+00 [cm]
zmin = 0.0000E+00 [cm]
zmax = 1.0000E+01 [cm]
part = photon

zmin 0.000E+00
zmin 1.000E+00
zmin 2.000E+00
zmin 3.000E+00
zmin 4.000E+00
zmin 5.000E+00
zmin 6.000E+00
zmin 7.000E+00
zmin 8.000E+00
zmin 9.000E+00
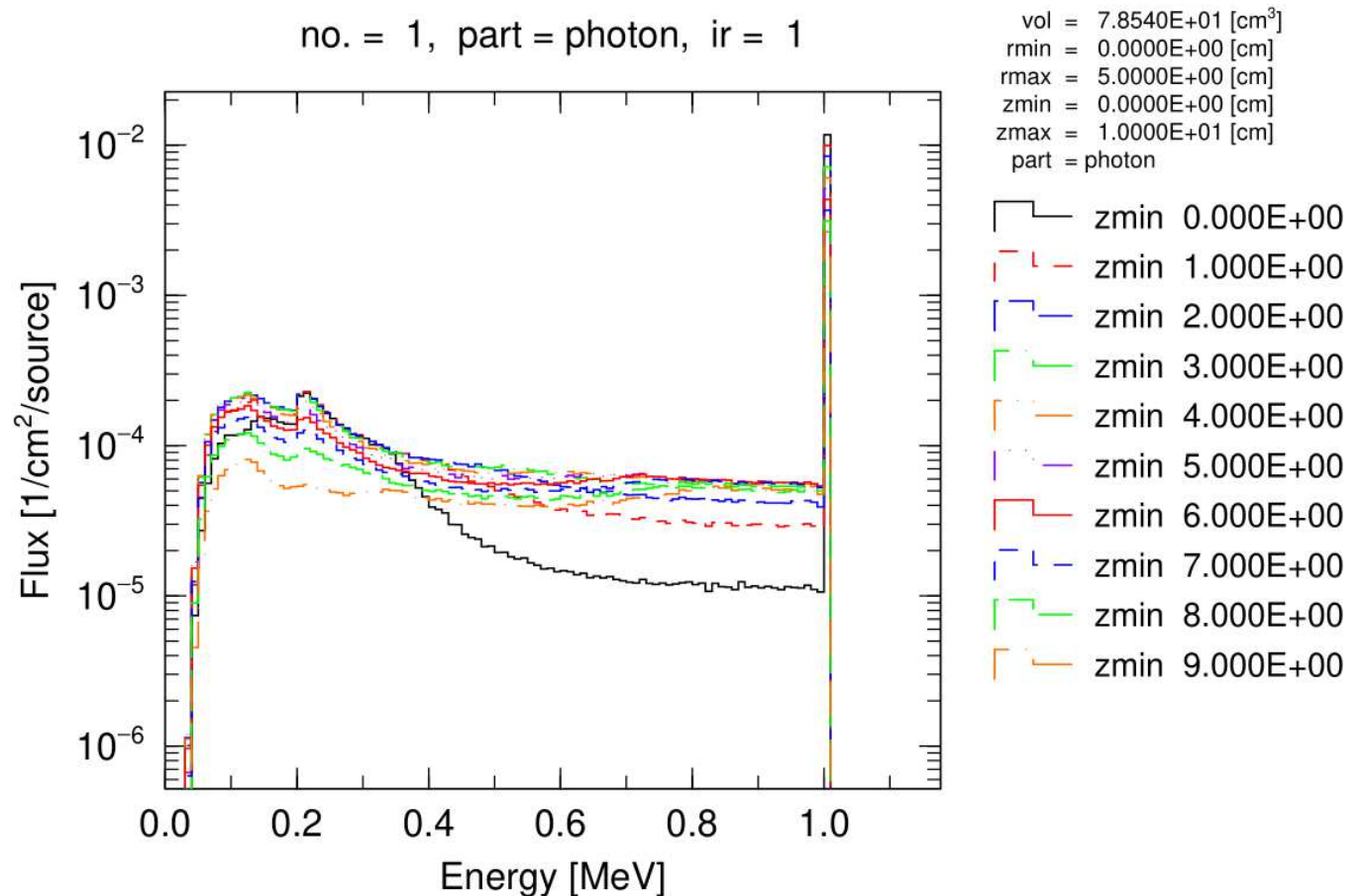
Display up to 20 data specified by "samepage"
parameter (in this case, z) in the same page

Direct comparison between the data for any "axis" parameter becomes feasible
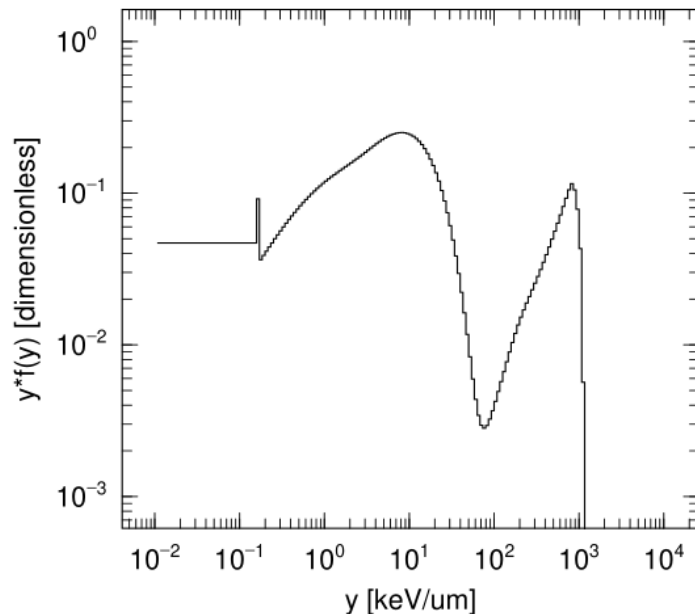
Development of a new model in [t-sed]

Old Model

Track-structure code

- ✓ TRACEL (Tomita et al. 1996)
- ✓ δ-ray production (Butts & Katz 1967)

Output microdosimetric quantities

ε (eV), y (keV/um), z (Gy)

Lineal energy distribution around the trajectory of 1 MeV/n ^{12}C ions for water targets with diameter of 100 nm
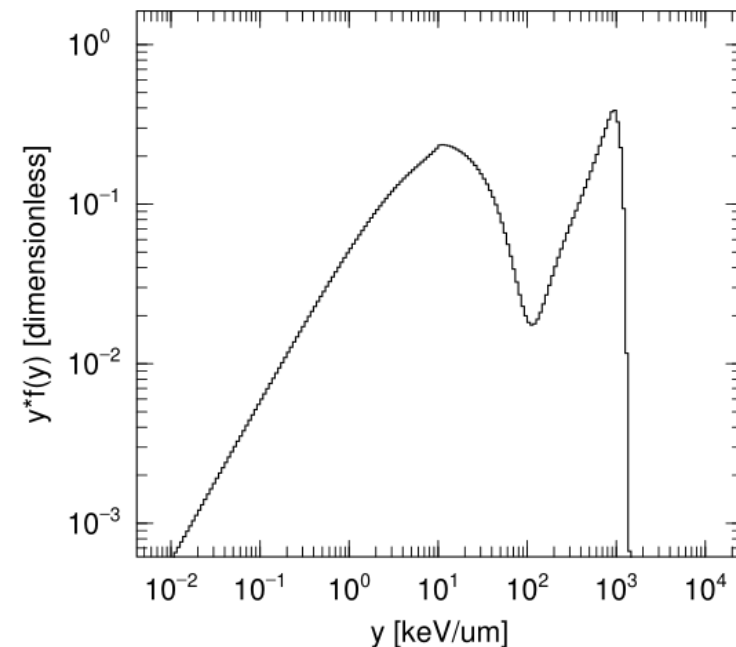
(Sato et al. 2006, 2009)

New Model

Track-structure code

- ✓ ETS mode (Kai et al. 2015)
- ✓ ITSART (Ogawa et al. 2021)

Output microdosimetric quantities

ε (eV), y (keV/um), z (Gy), $\underline{n_{ion}}$

Number of ionizations & electronic excitations
→ Useful for DNA damage yield estimation

(Sato et al. submitted)

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User Defined Model (PHITS-UDM)

✓ Users can implement their own "interactions" and "particles".
✓ Those extensions are easily shared with other users.

Example

1. Photons are generated by the electron beam

   (Up to this point, calculations can be made with normal PHITS)

2. User-defined particles are produced by a user-defined interaction of photons with water

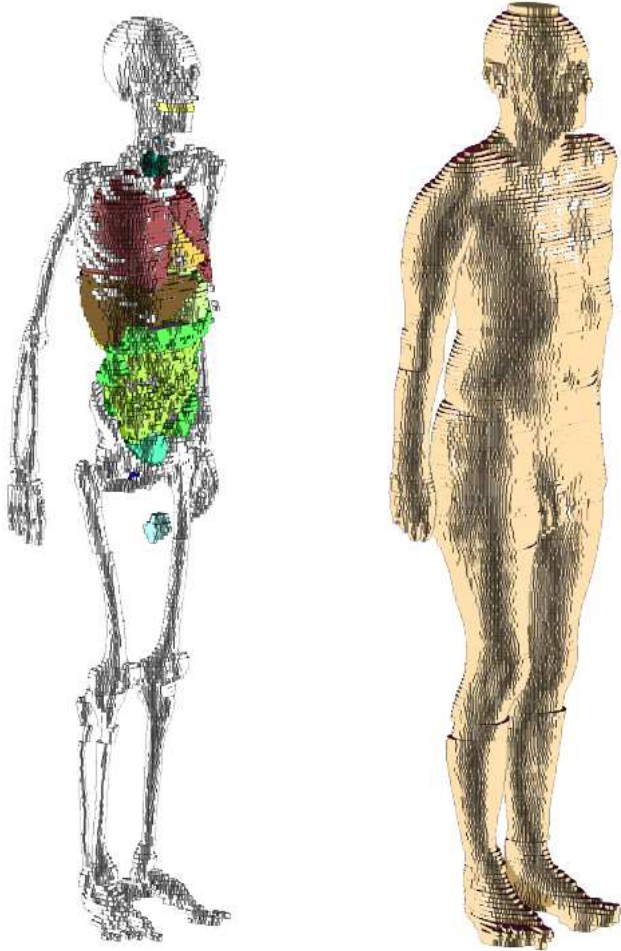   "kf-code" can be assigned to user-defined particles within the range:
   900000 < |kf-code| < 999999

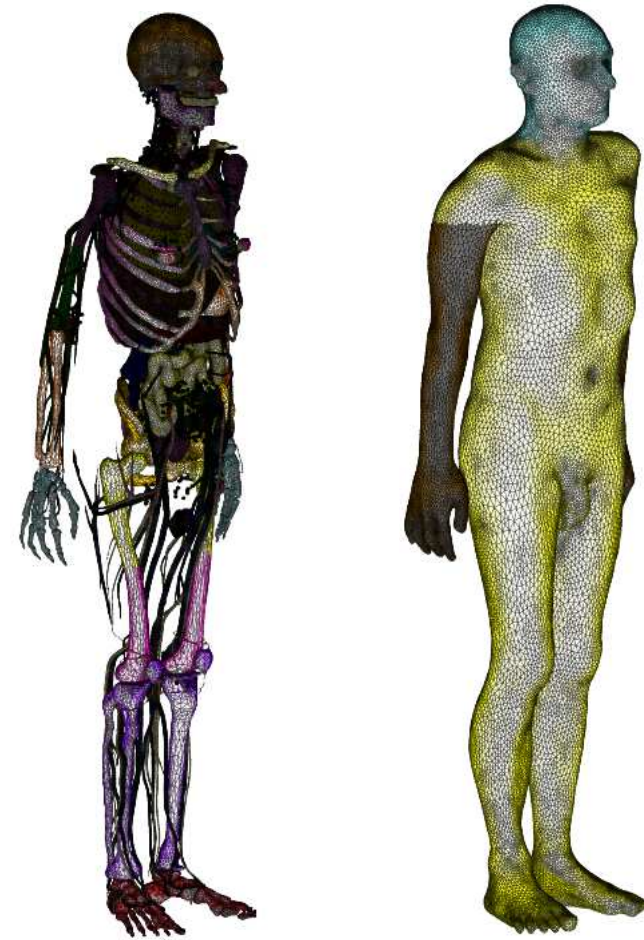3. The user-defined particles decay according to a specified lifetime and branching ratio

part = photon

Water (target)

part = 900000

part = nu_e

https://github.com/sakaki-y/PHITS-UDM
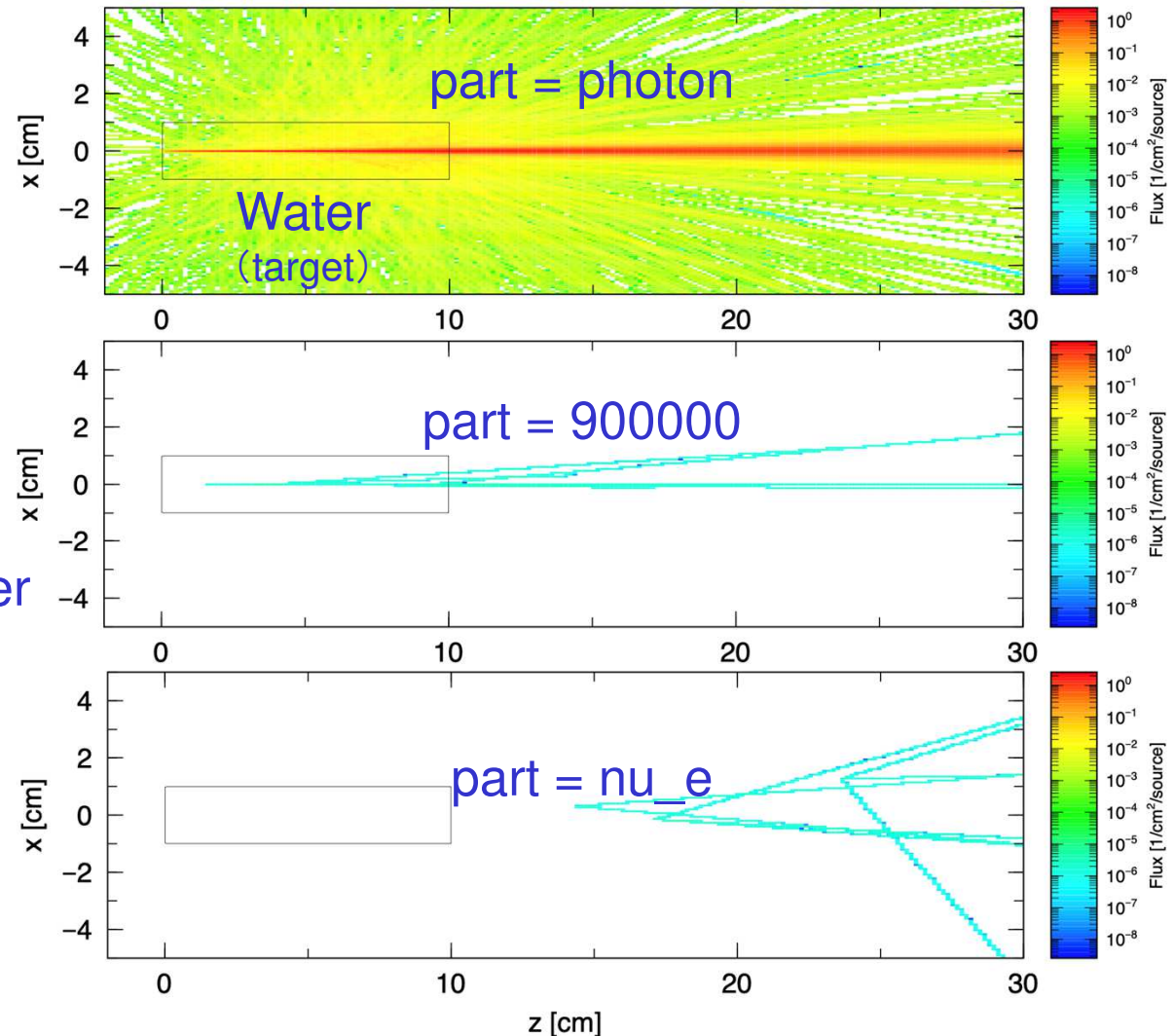
Incorporation of ICRP phantoms

Voxel Model

Mesh Model

Reference adult male and female phantoms in the PHITS input format are included in the PHITS package, based on the approval from ICRP

/phits/sample/icrp

Upcoming Futures

We are planning to …

➢ **Improve the track structure mode**
  - ✓ Extension of the precise mode applicable to other elements/compounds
  - ✓ Development of coupling modules connecting to material & life sciences

➢ **Improve affinity to nuclear data library**
  - ✓ Benchmark test of JENDL-5.0 and photonuclear data libraries

➢ **Develop user support functions**
  - ✓ Special editor for making PHITS input file
  - ✓ Improvement of RT-PHITS

➢ **Improve accuracy and nuclear reaction model**
  - ✓ Improvement of JQMD ver. 2.0 to be faster and more accurate
  - ✓ Improvement in the evaluation methods for both statistical & systematic uncertainty
  - ✓ Comprehensive V&V