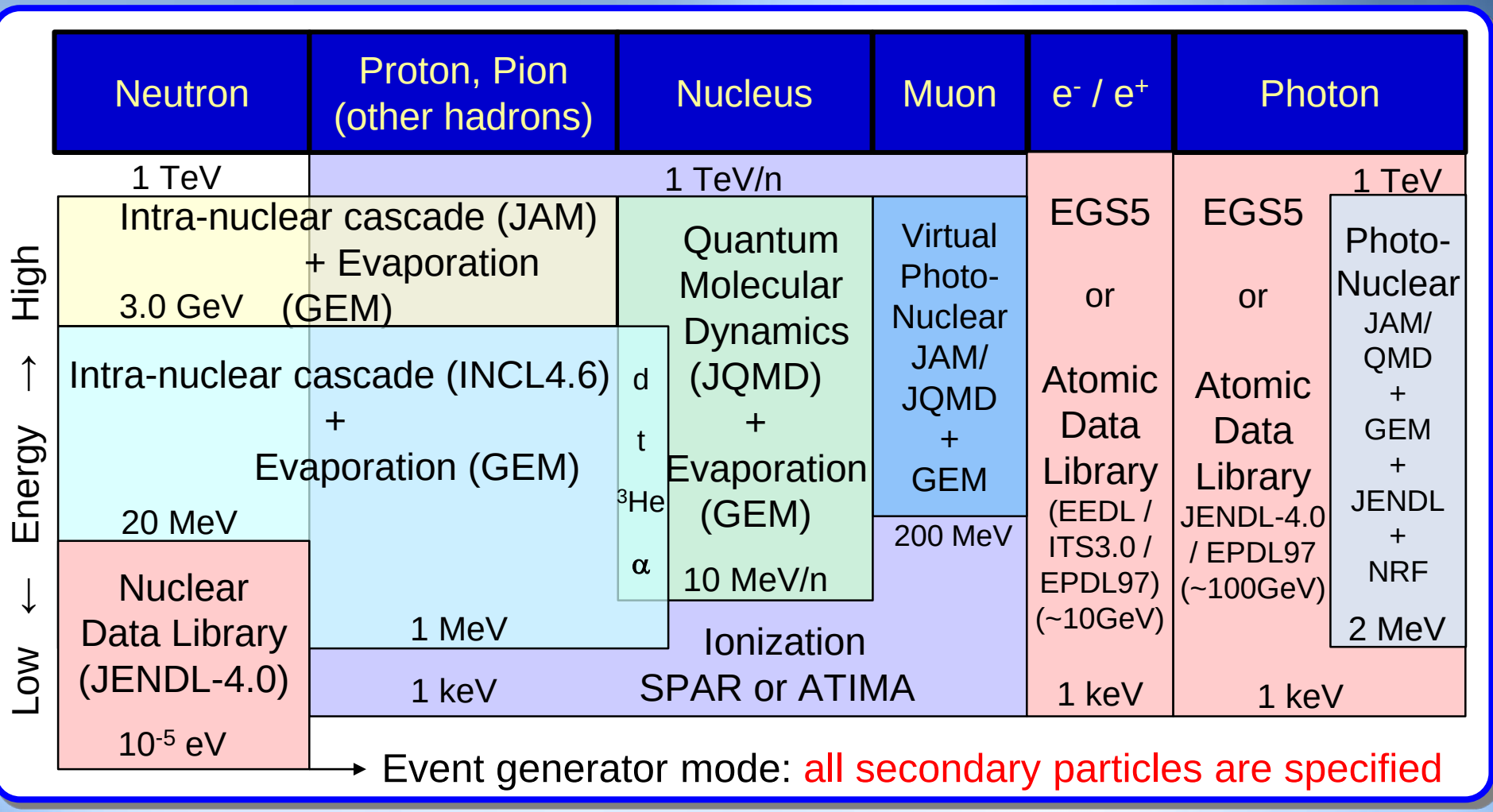
Features of PHITS2.88

PHITS development team, Sep. 2016

Map of Models used in PHITS2.82



Maximum energy is extended up to 1 TeV/n by fixing bugs in high-energy nuclear reaction models

*Switching energies can be changed in input file of PHITS

Major Upgraded Features in v2.82

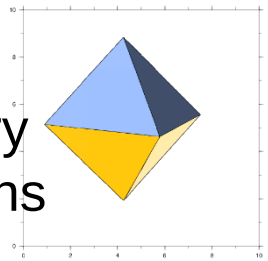
Upgrade Points from v2.88

- ✓ Implementation of function to read tetrahedral geometry
- ✓ Improvement of muon transport algorithm
- ✓ Implementation of nuclear resonance florescence model
- ✓ Extension of “sum tally”
- ✓ Implementation of function to read user defined cross section
- ✓ Revision of energy straggling calculation procedure
- ✓ Revision of statistical uncertainty calculation procedure using dump source
- ✓ Revision of bugs in EGS5 mode
- ✓ Implementation of point estimator tally [t-point]
- ✓ Implementation of R-θ-Z mesh in [t-track]
- ✓ Implementation of function to generate triangle prism source

Tetrahedral Geometry

✓ What's tetrahedral geometry?

A kind of 3D polygon geometry composed only by tetrahedrons



✓ What's the purpose of implementation?

Read complicated geometry such as human body

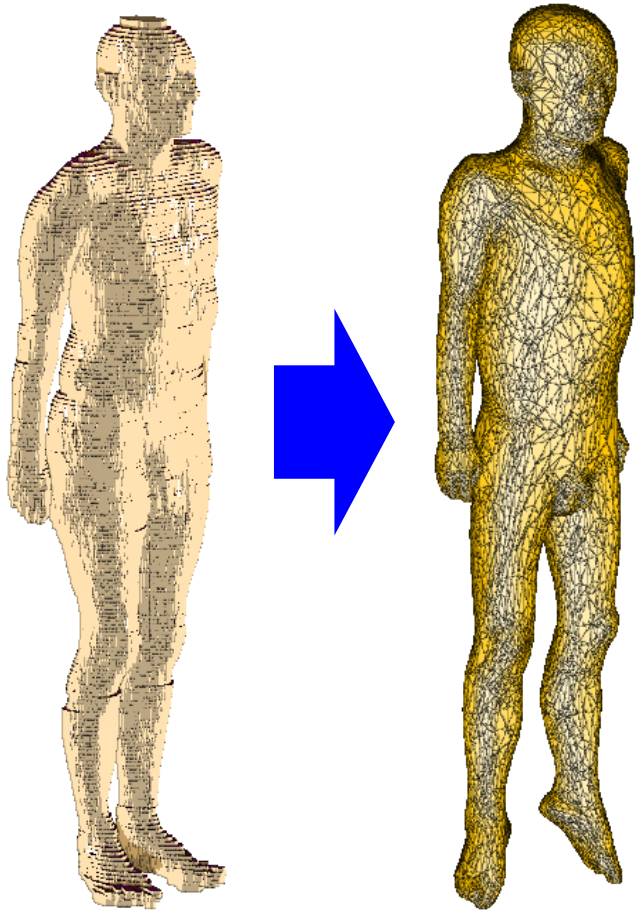
Read CAD geometry via tetrahedral geometry

✓ How to use? (see utility/TetraGeom)

Similar to voxel geometry

You have to prepare tetrahedral geometry using other software such as TetGen*

* http://wias-berlin.de/software/tetgen/



Voxel phantom (ICRP [1])

Polygon phantom (Hanyang Univ. [2])

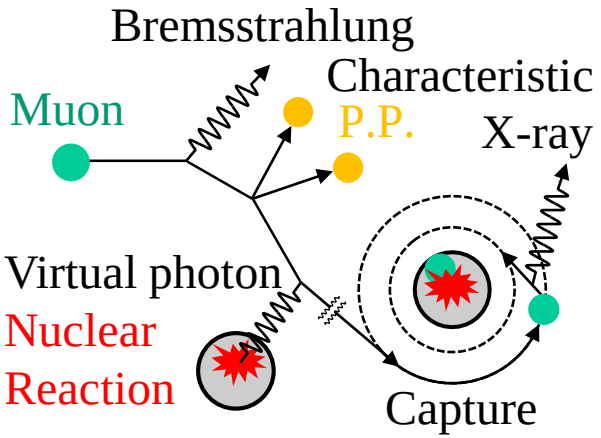
[1] ICRP Publication 110, [2] Y.S. Yeom et al. Phys. Med. Biol. 59, 3173-3185 (2014)

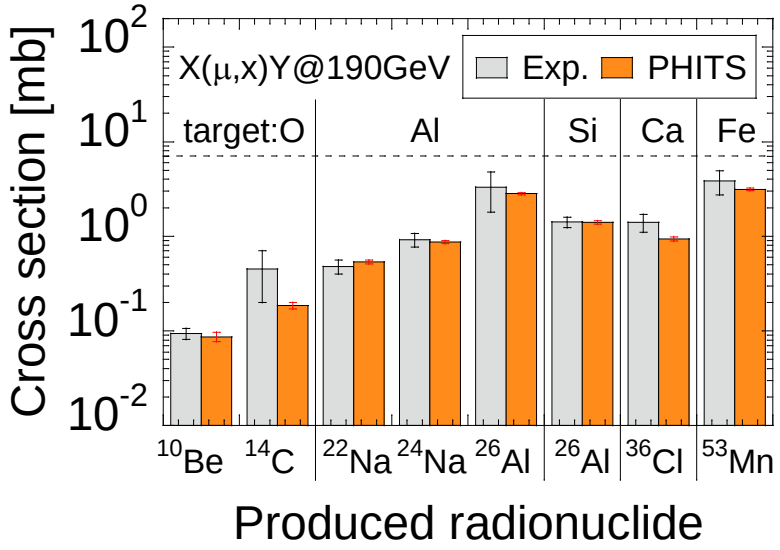
This implementation was performed under support of Prof. C.H. Kim's group of Hanyang Univ

Improvement of Muon Interaction Models

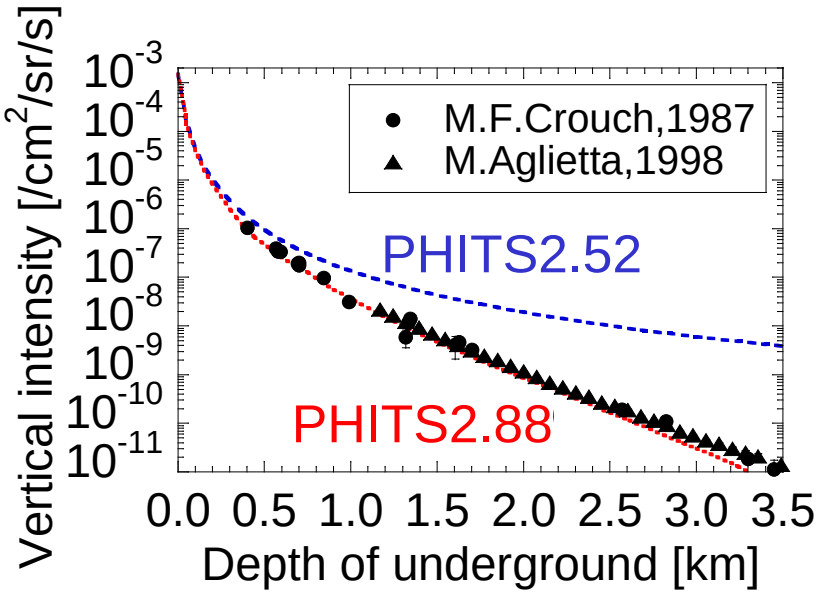
- Muon-induced nuclear reaction (ver.2.70)
- Negative muon capture reaction (ver.2.76)
- Bremsstrahlung, pair production (ver.2.80)

➡ All interaction can be considered!!





Muon-induced nuclear reaction



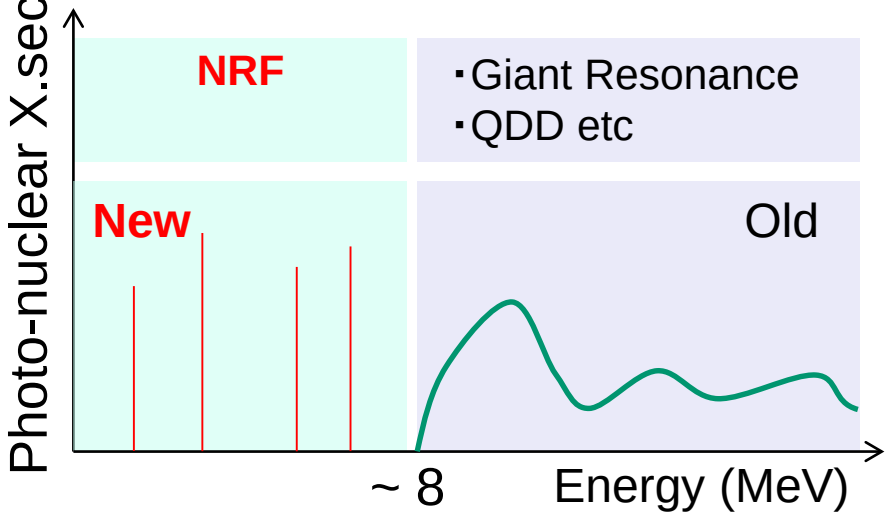
Underground muon penetration

S. Abe and T. Sato J Nucl Sci Technol. (2016) doi: 10.1080/00223131.2016.1210043

Nuclear Resonance Florescence (NRF)

What's NRF?

Nucleus can absorb photon with energy equivalent to its excite level, and emit gamma-ray with certain energies (a kind of photo-nuclear reaction)



Application

- ✓ Estimation of radioactivity after food irradiation
- ✓ Detection of nuclear material

How to use

1. Set ipnint = 2 in [parameters] section
2. Set polarization direction in [source] section (for polarized photon)
3. Set igamma = 3 if you would like to calculate isomer production

Absorption levels are mostly taken from ENSDF (http://www.nndc.bnl.gov/nudat2/)

T. Ogawa et al. J. Nucl. Sci. Technol. 53, 1766-1773 (2016)

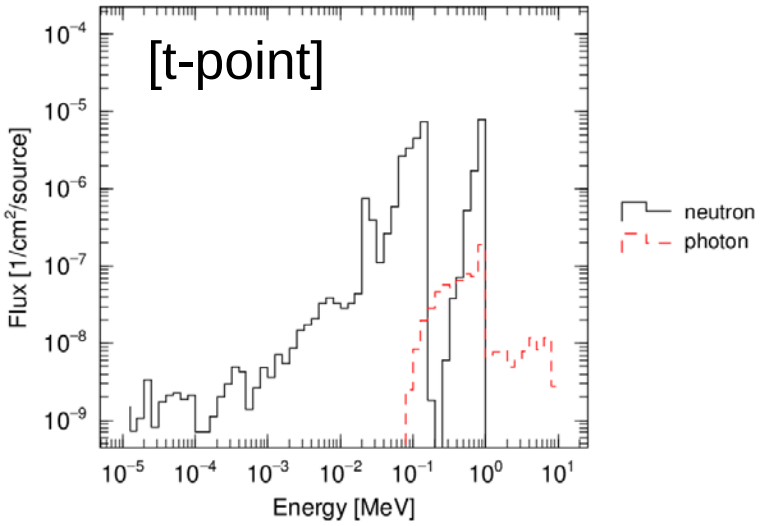
Point Tally [t-point]

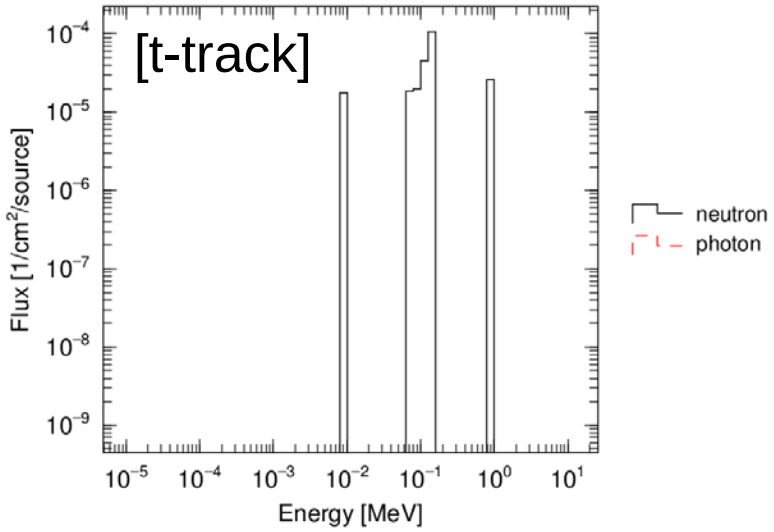
What's point tally?

Estimate particle fluence at a certain point (or line)
Effective when tally region is very small in comparison to whole geometry

Simulation Condition

- ✓ Simulation using only nuclear and atomic data libraries
- ✓ Only fluence of neutron and photon can be estimated
- ✓ Neither event-generator and EGS5 mode cannot be used





Neutron and photon fluence calculated by [t-point] and [t-track] for similar conditions

Major Upgraded Features in v2.88

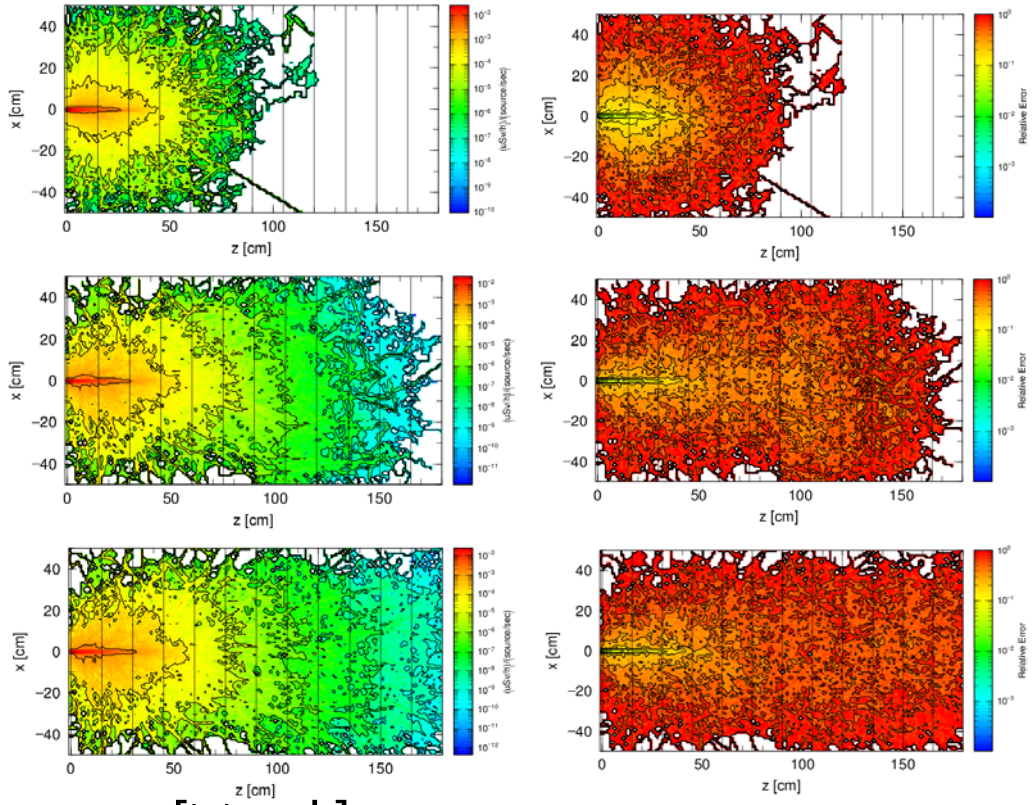
Upgrade Points from v2.82

- Implement Weight Window Generator function
- Develop output option for a 3D-viewer ParaView
- Set ATIMA for default stopping power calculation model
- Improve “sum tally” function
- Improve muon and pion nuclear interaction models
- Implement radioisotope source function
- Develop JAMQMD
- Implement neutron decay process
- Revise some bugs in the EGS5 algorithm

Weight Window Generator

What can do with Weight Window Generator [t-wwg]?

- ✓ Automatically determine the effective settings of [weight window]
- ✓ Help users to easily perform deep penetration calculation



[t-track] Relative Error

1st trial
No [Weight Window]

2nd trial
Using [Weight Window]

3rd trial
Revised [Weight Window]

Deep penetration calculation using [t-wwg] & [Weight Window]

(history numbers are the same for all trial)

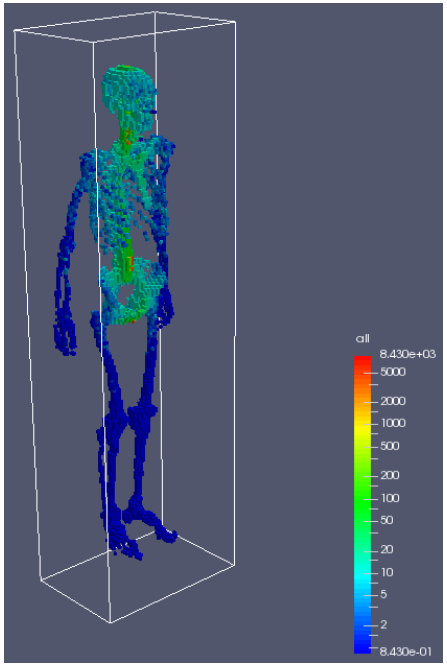
Output Function for ParaView

What's ParaView (http://www.paraview.org)?

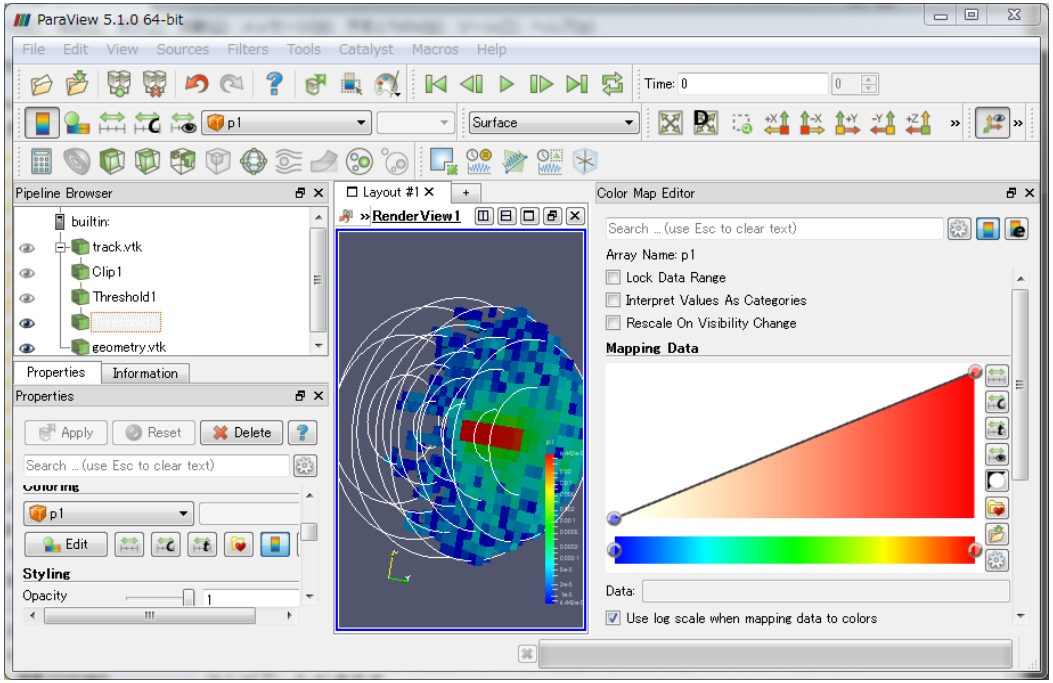
- ✓ Open-source, multiplatform data analysis and visualization application
- ✓ Capable of drawing tally outputs in 3D picture & animation

How to activate the function?

Simply add "vtkout = 1" in a tally with "mesh = xyz"



ICRP voxel phantom visualized by ParaView



Sample picture of ParaView

See lecture¥advance¥paraview in more detail

RI Source Function

What can do with RI source function?

- ✓ generate photon sources with energy spectra of radioisotope (RI) decay by simply specifying the activity and name of the RIs
- ✓ consider activities from daughter nuclides by setting a decay time
- ✓ use nuclear decay database DECDC*

RI source (e-type = 28)

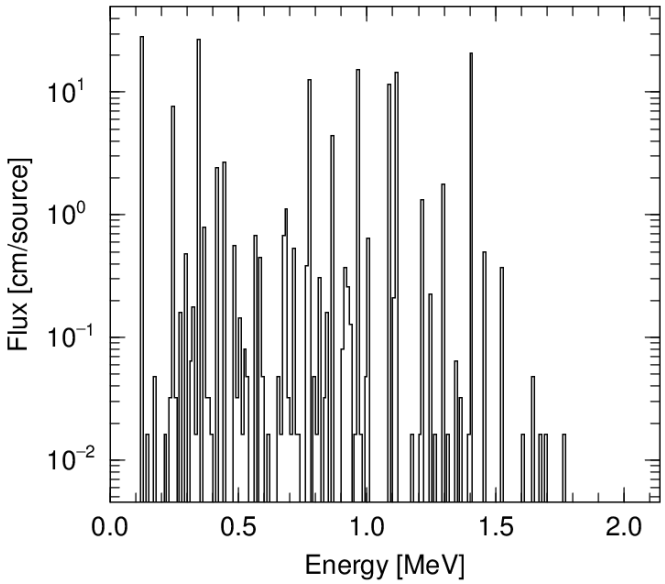
```
[ Source ]
factor = 1.0
…
e-type = 28
   ni  =  1
  152Eu 100.
  norm = 0
 dtime = -10.0
```

dtime:
decay time

Mono-energetic source (e-type = 8)

```
[ Source ]
factor = 100.*1.6051
…
e-type =  8
   ne  =  32
   1.21782E-01 100.*2.86678E-01
   1.25690E-01 100.*1.61100E-04
   1.48010E-01 100.*3.73216E-04
   1.73170E-01 100.*7.96740E-05
…(repeated)
   1.69810E+00 100.*5.90701E-05
   1.76909E+00 100.*9.58546E-05
```

Input formats for representing ^{152}Eu with activity of 100 Bq



Photon flux from ^{152}Eu

*A. Endo et al., JAERI 1347 (2005); equivalent to ICRP Publication 107