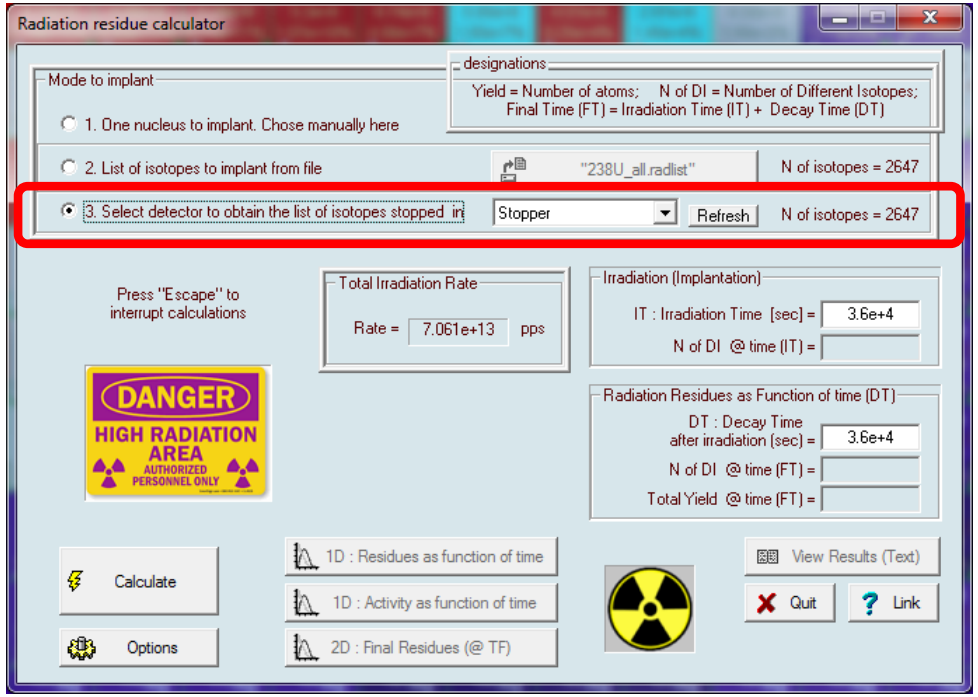
Isotope Production in the FRIB Beam Dump : ^{238}U case

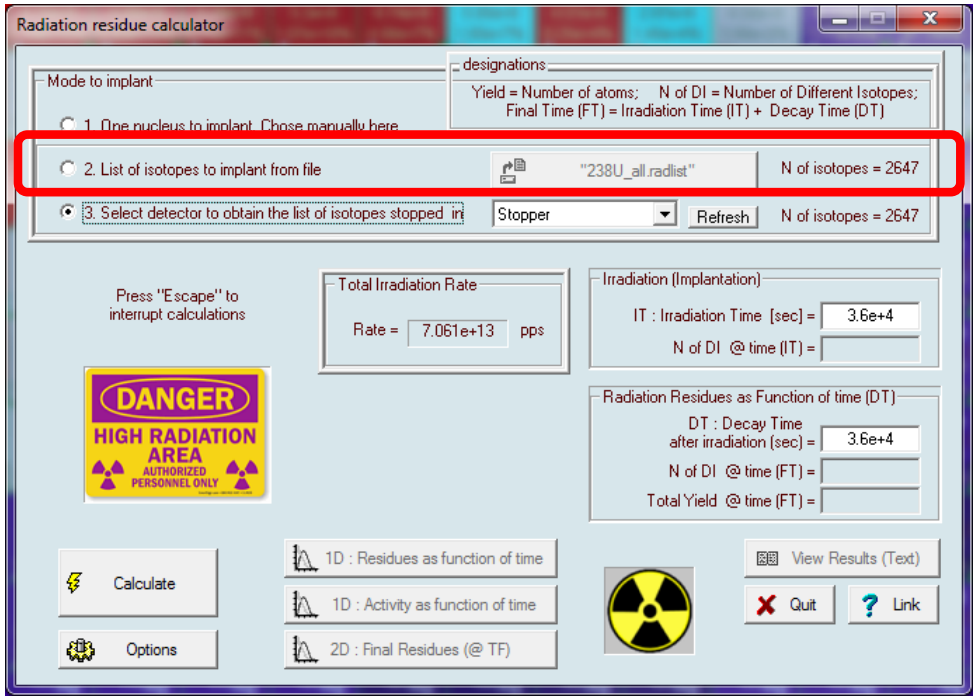
- How to get isotope yields in the beam dump with the Uranium beam?
- Production settings : why a Li-target was used?
- Radiation residues calculator : $T_{1/2}$ boundaries against the “stiffness” problem
- Link to the “Isotope Production in the FRIB Beam Dump : projectile fragmentation case” presentation

Isotope yields in the beam dump with the Uranium beam : Files

Options :

1. You can use the LISE^{++} file
http://lise.nscl.msu.edu/work/BeamDump/AF_238U_Li.lpp
and then Mode #3 (Select detector) in the Radiation residue calculator





2. Or You can use the Radiation list file obtained with AF_238U_Li.lpp
http://lise.nscl.msu.edu/work/BeamDump/238U_all.radlist
and then Mode #2 (List of isotopes to implant from file) in the Radiation residue calculator

Please download the latest LISE^{++} version **9.10.371** from 10/28/16

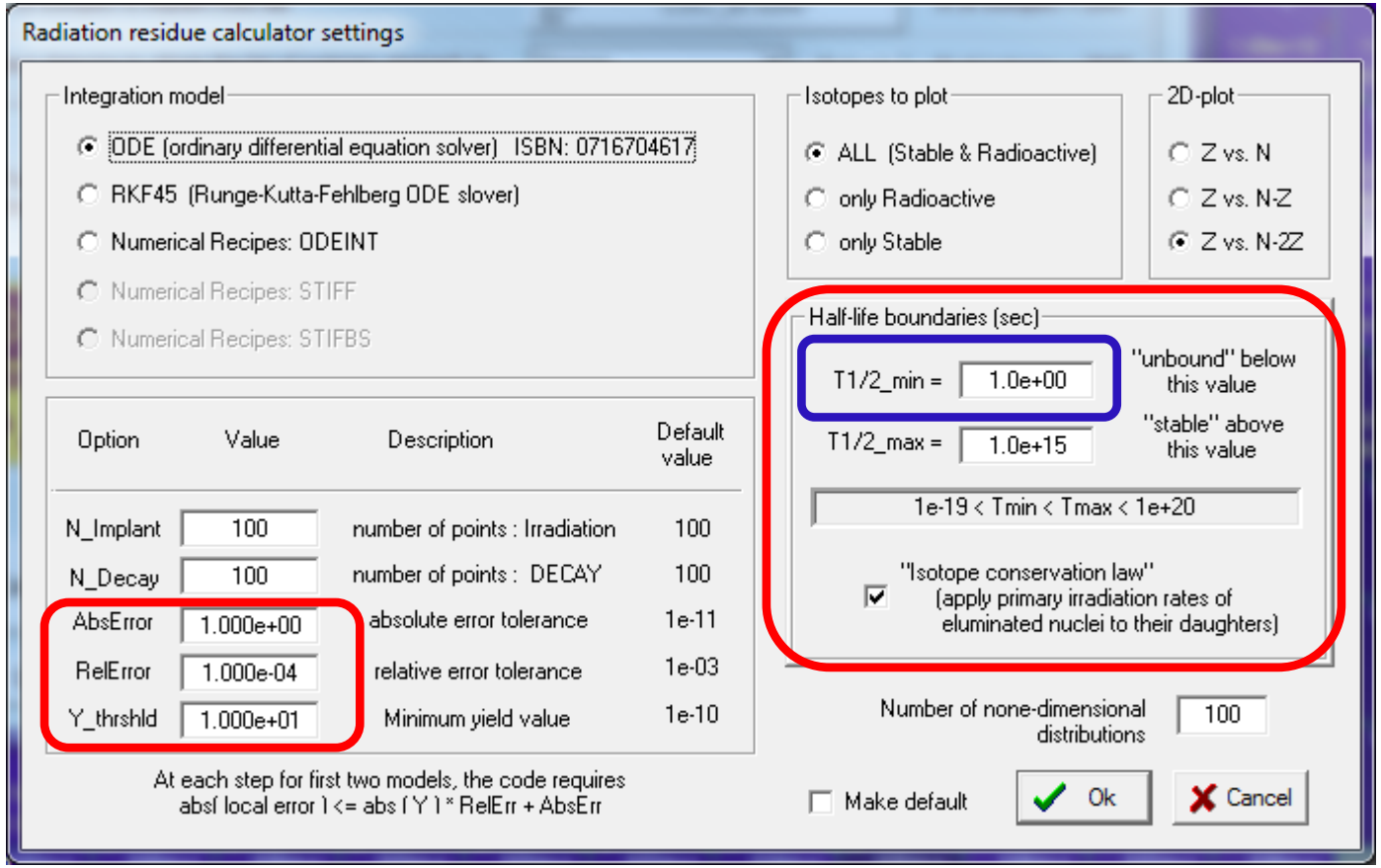
to overcome the stiffness problem in the Radiation Residue Calculator.

See the "Radiation residues calculator : T1/2 boundaries against the "stiffness" problem" page in this presentation

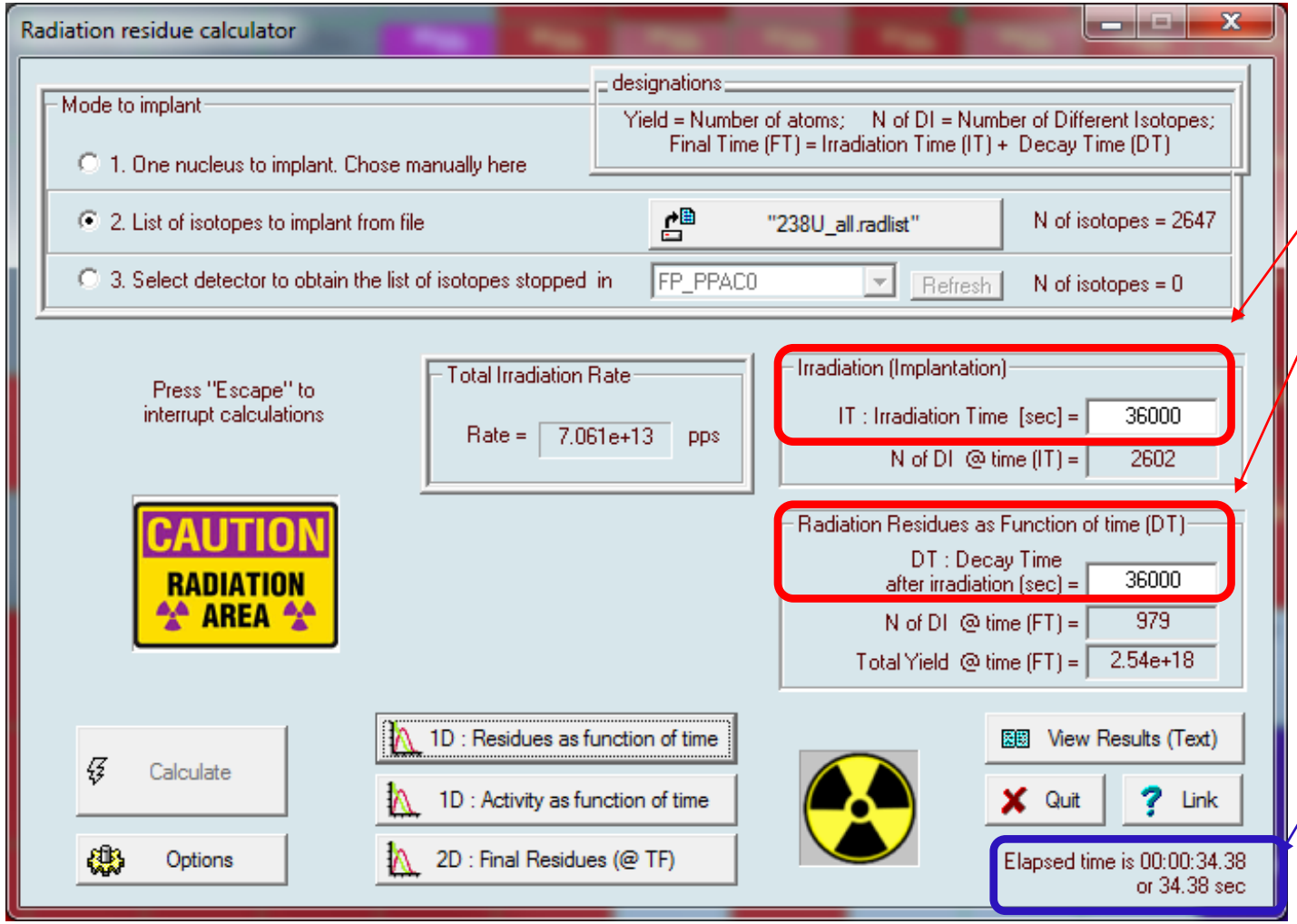
Use the next options for the Radiation Residue calculator:

1. Total irradiation is 7.1e13 pps, and we are interested in isotopes with residual yield > 10^5, so it is possible to increase the global threshold up to 10 for fast calculations avoiding low-yield production

2. The decay time is expected more than one hour (that it is obtained from chemistry), so **please set the $T_{1/2}$ *min* boundary *(important!)*** equal to 1 sec assuming short-lived products be unbound for fast calculations.



Calculations with the Radiation residues calculator



After settings of the Radiation Residue calculator options, please, enter the “Irradiation” and “Decay” times (10 h & 10 h in this example).

Press “Calculate”

Pay attention for “stiffness” flag appearance, and change settings.

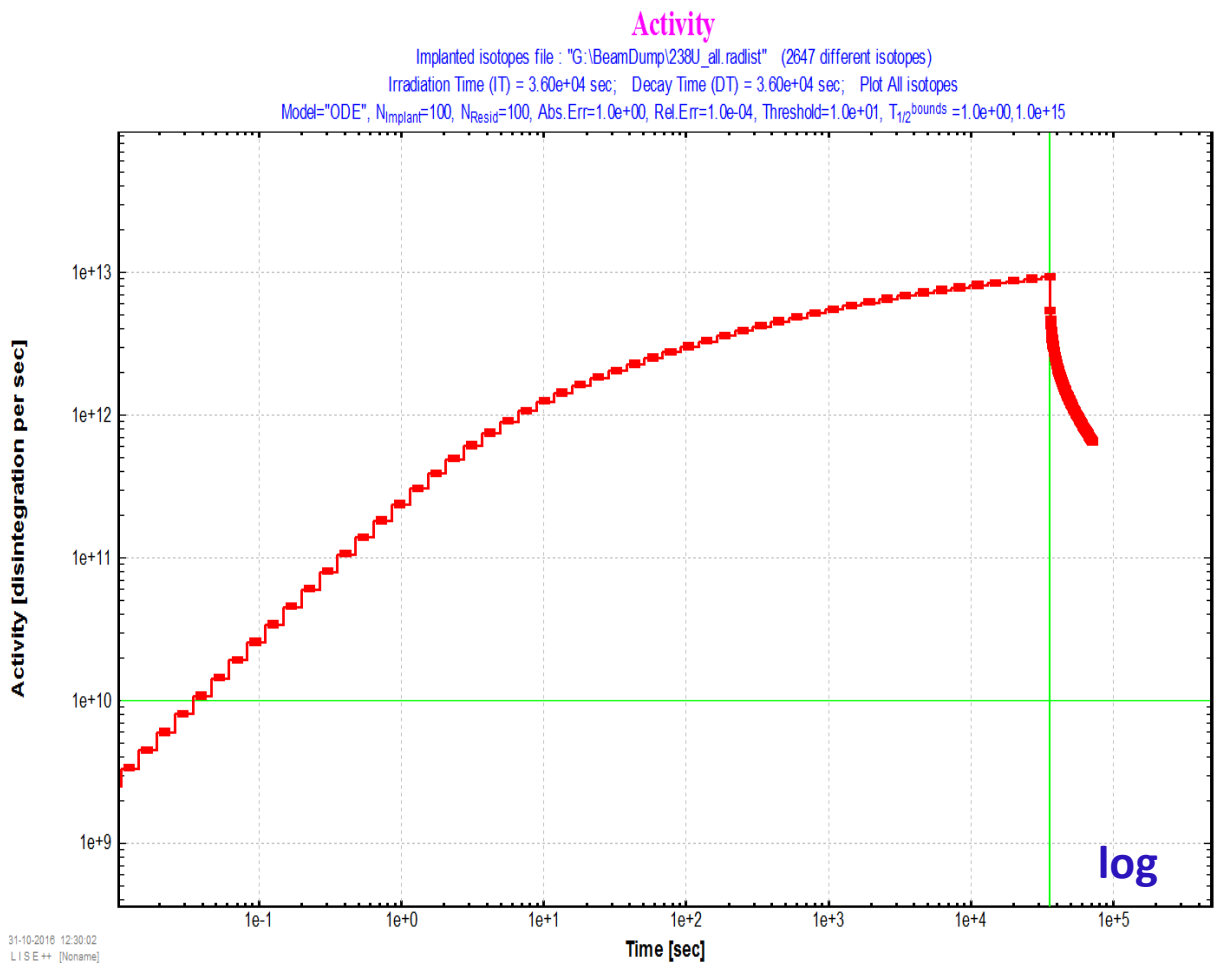
In the shown here example there was not stiffness problem.

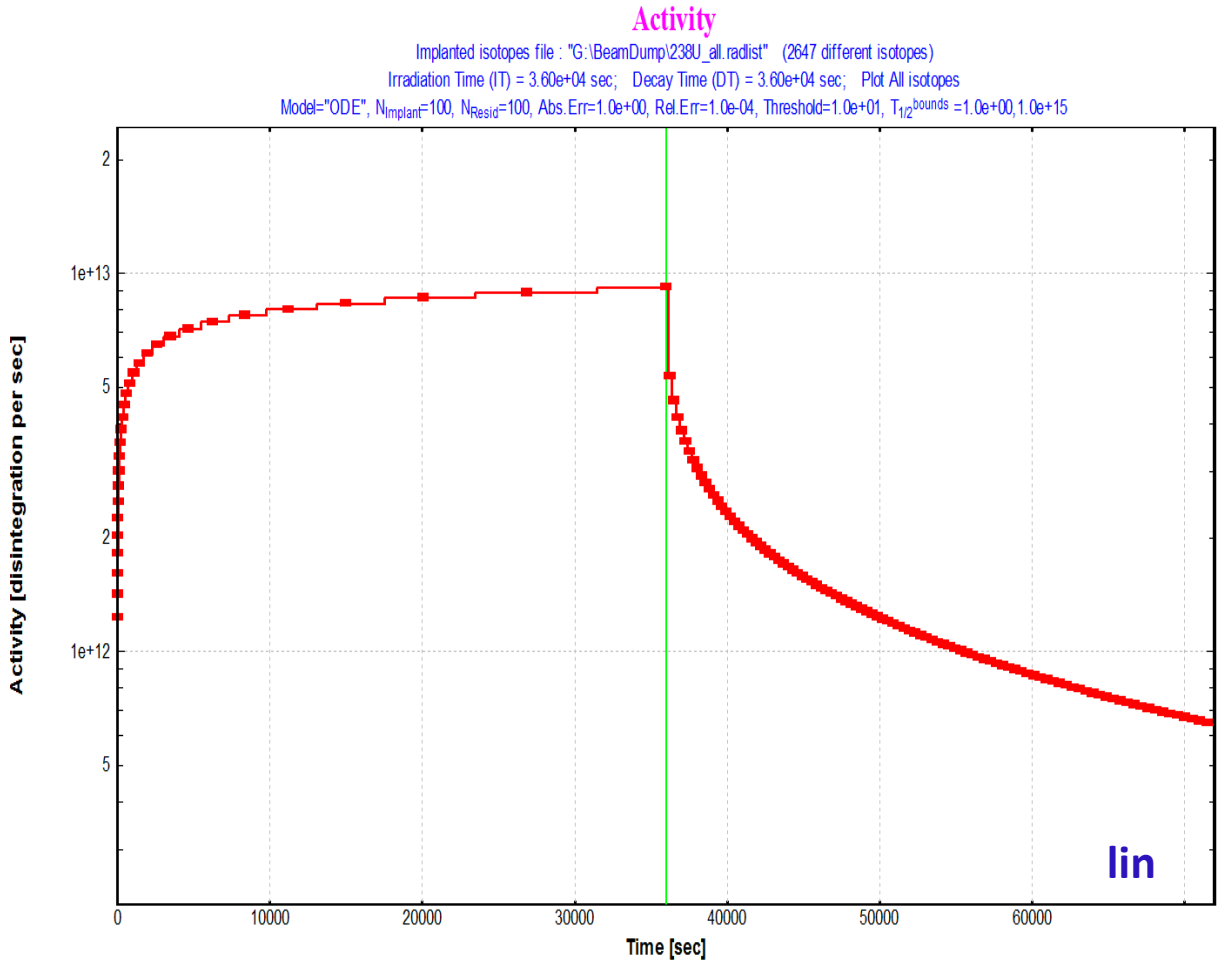
Elapsed time is 34 seconds

Rate x IrradiationTime should be equal to Total Yield @ Final time .
If not, so there are some leaks may be due to low error tolerance in the ODE solver, stiffness problem, or violation of “Isotope conservation law”

In this example no any leak:
7.063e13 * 3.6e4 = 2.54e18

Calculation results : Activity





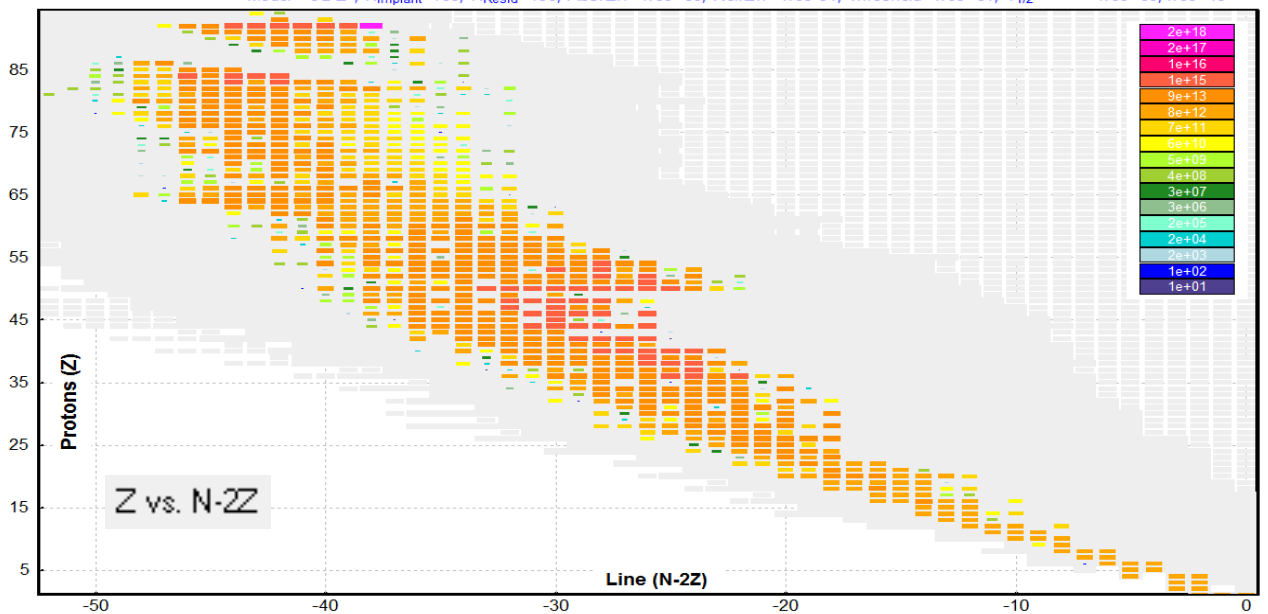
Calculation results : 2D final plots

2D-plot

- Z vs. N
- Z vs. N-Z
- Z vs. N-2Z

Radioactive decay residues

Implanted isotopes file : "G:\BeamDump\238U_all.radlist" (2647 different isotopes)
Irradiation Time (IT) = 3.60e+04 sec; Decay Time (DT) = 3.60e+04 sec; Plot All isotopes
Model="ODE", $N_{Implant}$=100, N_{Resid}=100, Abs.Err=1.0e+00, Rel.Err=1.0e-04, Threshold=1.0e+01, $T_{1/2}^{bounds}$ =1.0e+00,1.0e+15



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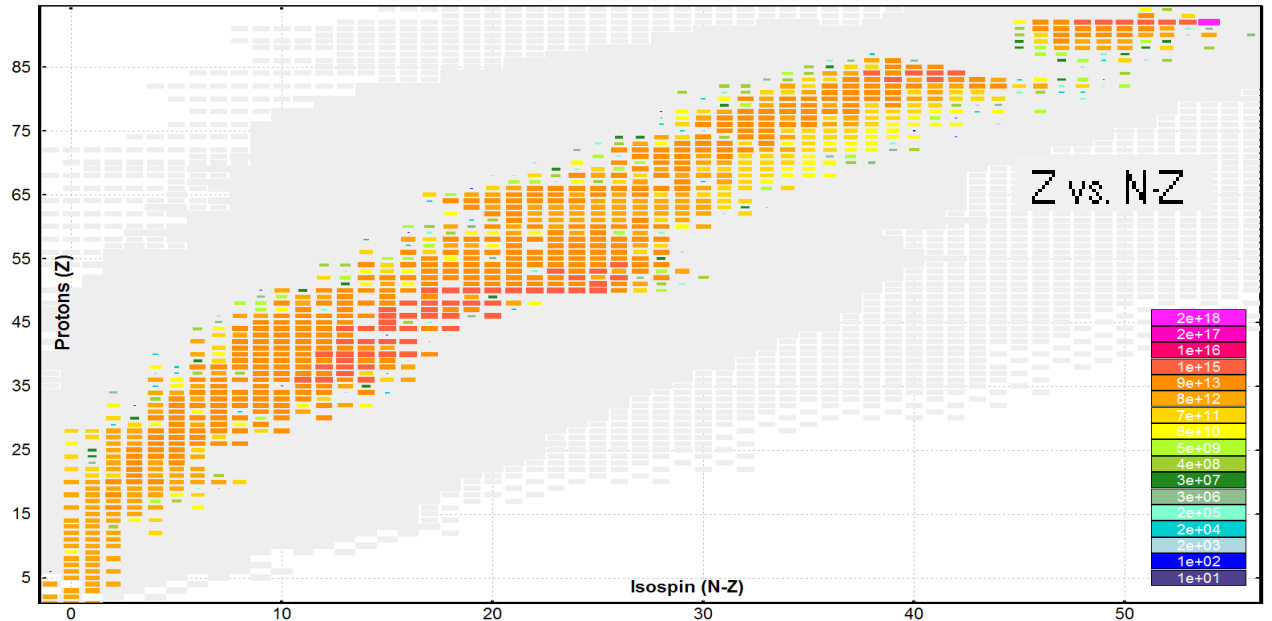
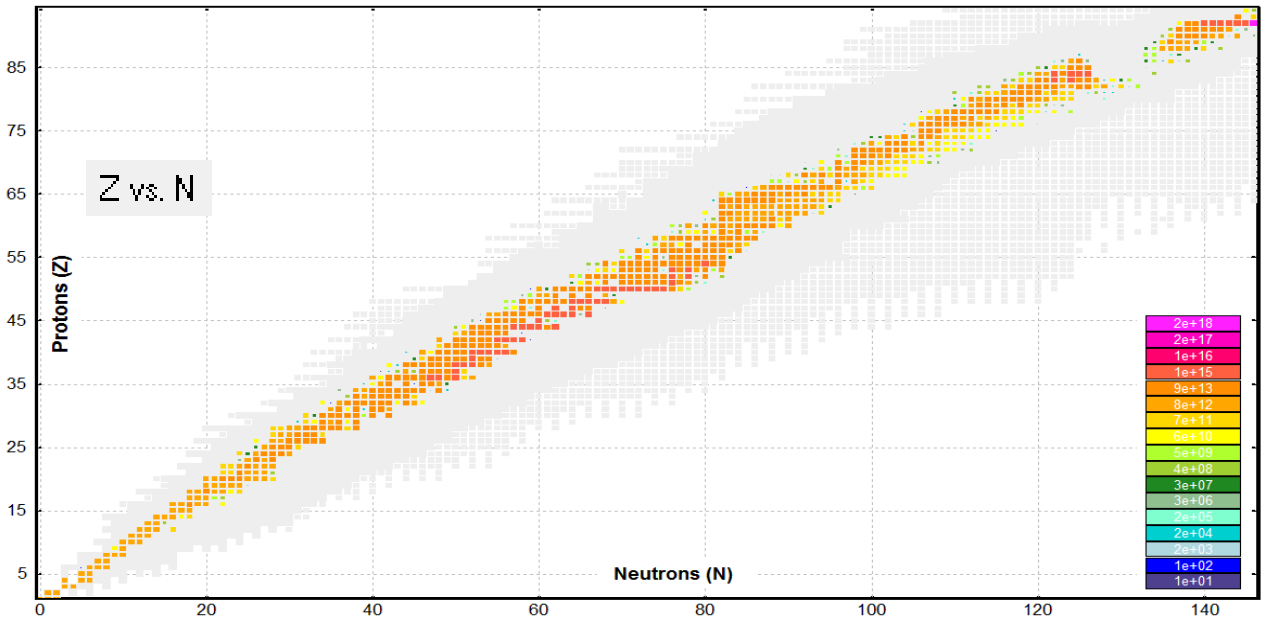
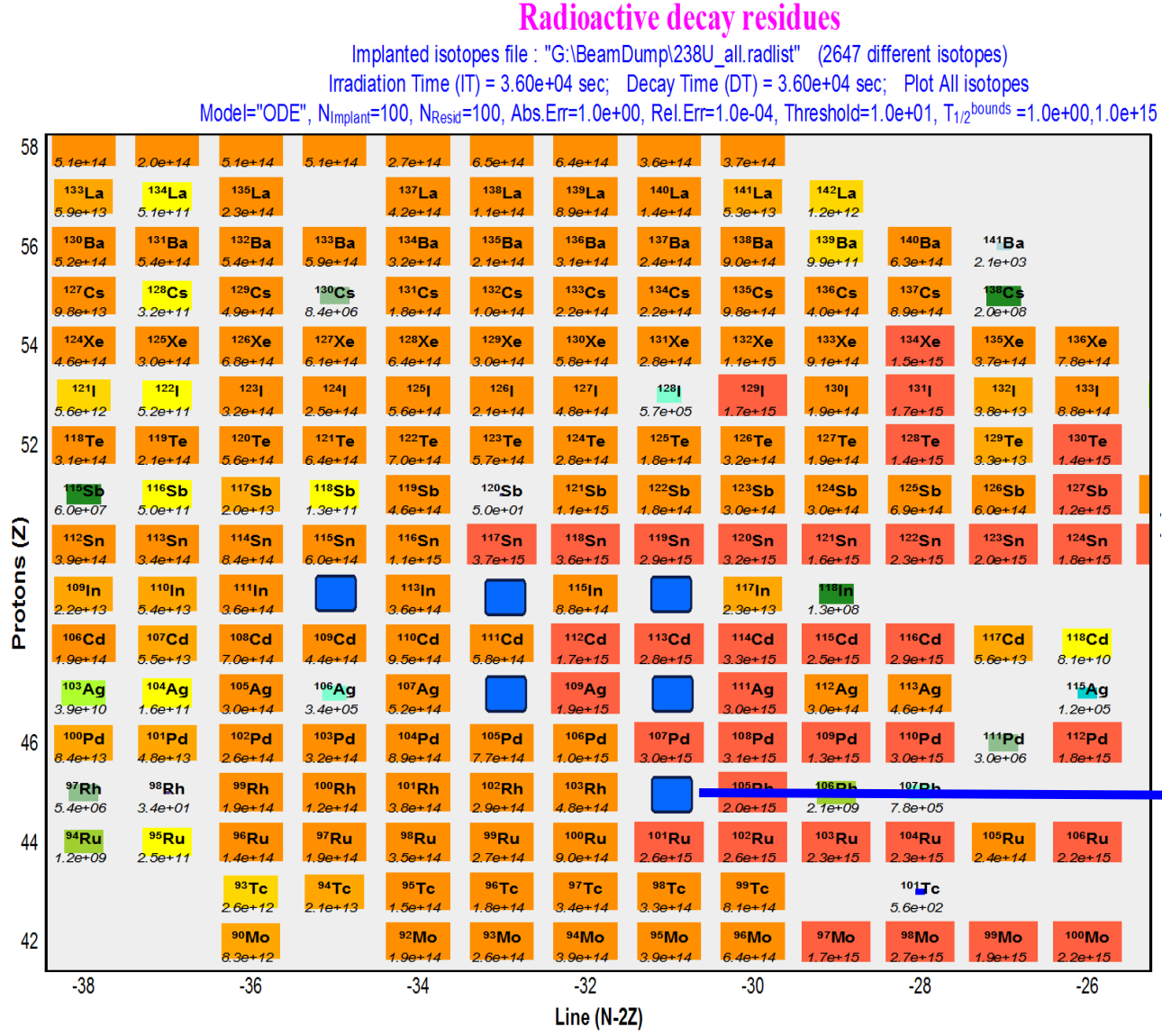
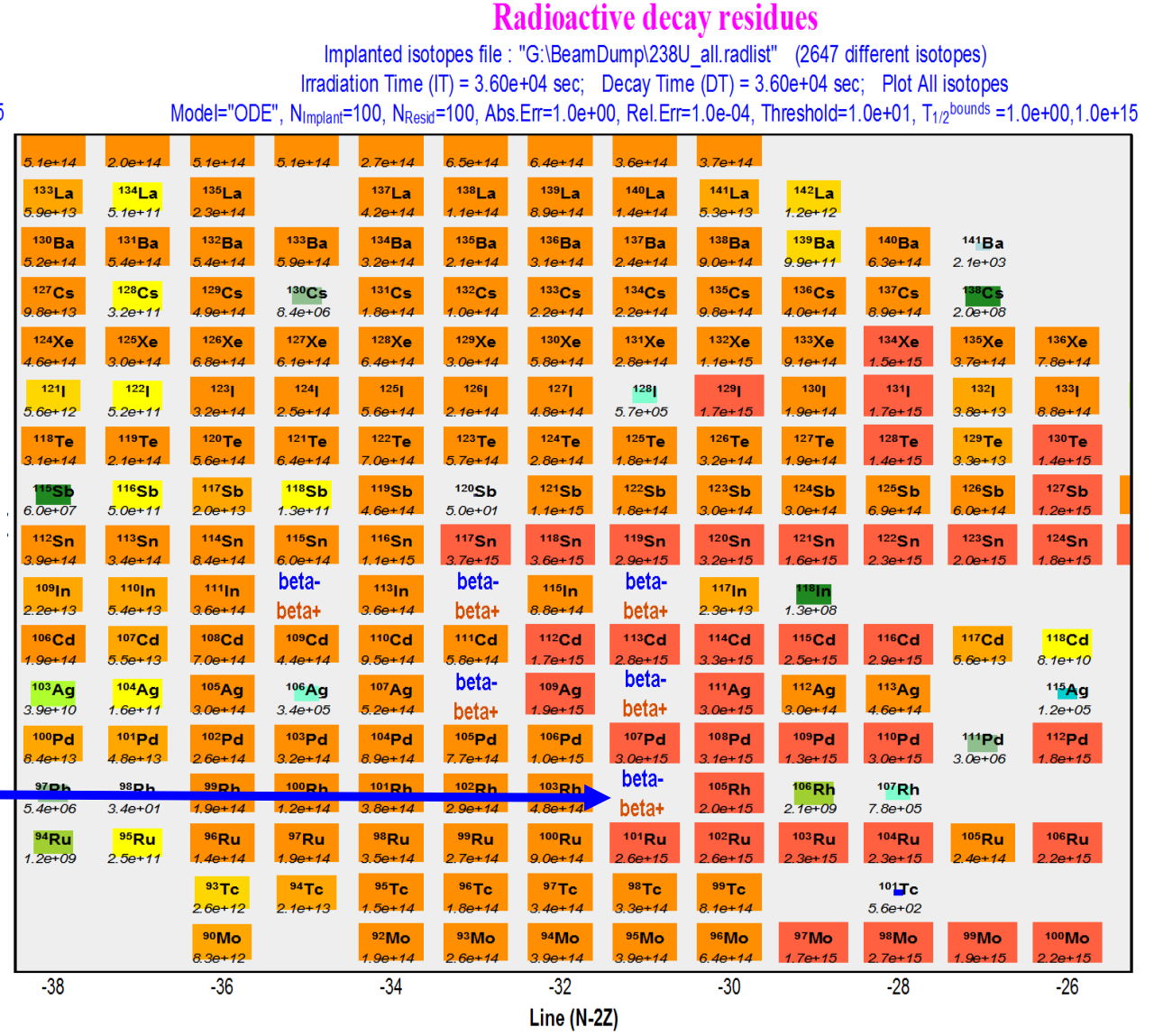


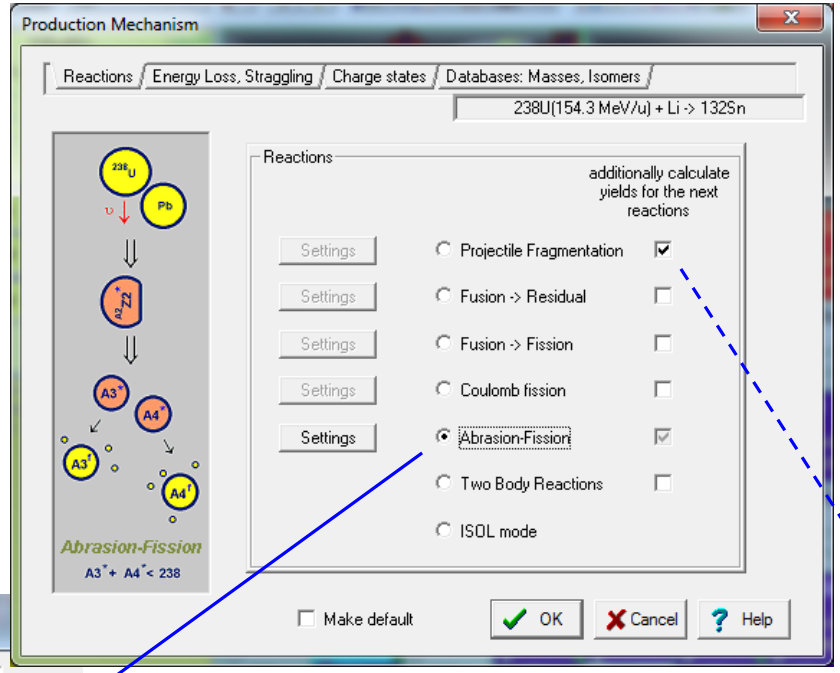


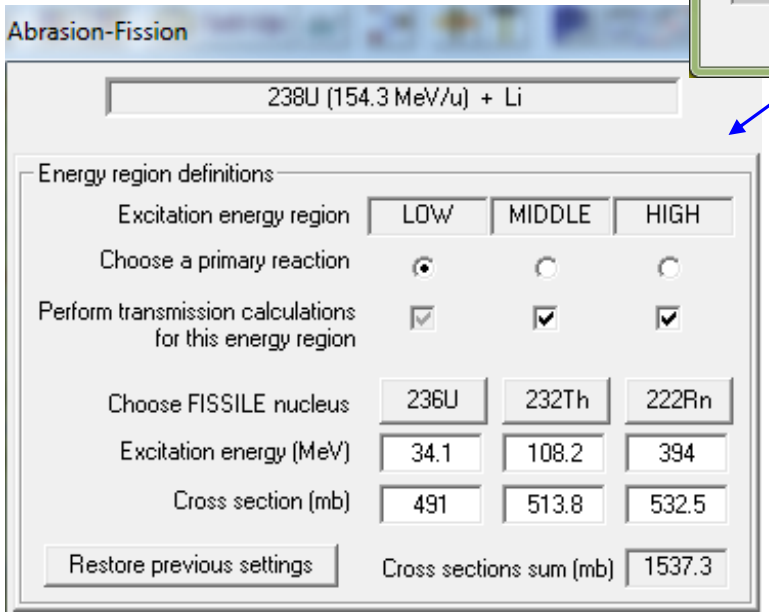
2D final plot : ZOOM

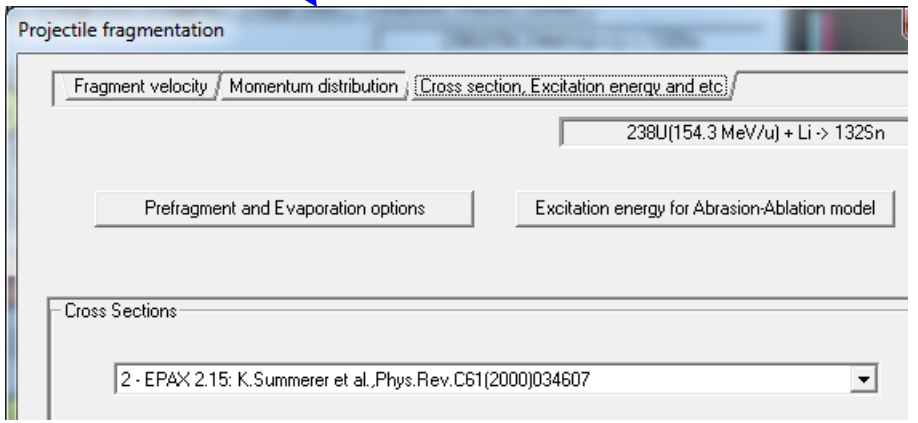




Uranium beam @ beam dump : Production mechanism







Production settings

Beam dump materials

- Ti90 Al6 V4 window : thickness* = 1 mm
- Water : thickness** = 2.09 mm

** Its equivalent is pure Ti material a thickness of 1.011 mm*

*** In the case of the Uranium beam*

- *LISE^{++} does not calculate isotope Abrasion-Fission production in compounds*
- *And…. There are two compound targets*
- *It is necessary to find an equivalent target*

Equivalent target

There are two conditions for equivalent target :

- *(Production mechanism condition) Number of fission reactions should be the same in the original (*Ti90 Al6 V4 window + Water) case and its equivalent
- *(Energy loss condition)* The Uranium primary beam passes the equivalent target and stops in a downstream material.

material	Atoms	Abrasion-Fission CS			Thick	NA	"Quasy" Yield
	in 1 mg/cm2	*mb*			*g/cm2*	*atoms*	*CS*NA*
H	5.97E+20	1101.3			0.023	1.39E+22	1.53E+25
O	3.76E+19	1652.2			0.185	6.97E+21	1.15E+25
H2O	1.00E+20	1284.9		target2	0.209	**2.09E+22**	**2.69E+25**
Ti	1.26E+19	1869.7		target1	0.457	**5.76E+21**	**1.08E+25**
Li	8.60E+19	1538.2			0.253	2.18E+22	3.35E+25
				target1+target2		**2.67E+22**	**3.76E+25**

	Thickness from NA	Thickness from Yield		Thickness
	g/cm2	g/cm2	delta %	average
H	4.47E-02	5.72E-02	22%	5.09E-02
O	7.09E-01	6.06E-01	15%	6.57E-01
H2O	2.67E-01	2.93E-01	9%	2.80E-01
Ti	2.12E+00	1.60E+00	25%	1.86E+00
Li	3.10E-01	2.84E-01	**8%**	2.97E-01

Smallest delta is observed in the case of Li-material. The best equivalent material

Final equivalent target thickness

Radiation residues calculator :

$T_{1/2}$ boundaries against the "stiffness" problem

http://lise.nscl.msu.edu/work/BeamDump/RadResCalc_v2a.pdf

^{221}U irradiation case : summary

		@ Final Time			
T1/2 min boundary	Decay time, s	Number of isotopes	Total yield	Activity	Elapsed calulation time
1E-08	0	13	1E+09	3.0E+11	6.07
1E-05	0	10	1E+09	5.0E+09	1.73
1E-02	0	9	1E+09	1.5E+07	0.57
				@ 1 &10 sec	
1E-08	100	11	1E+09	1.5E+07	9.09
1E-02	100	11	1E+09	1.5E+07	0.81

Link to

the “Isotope Production in the FRIB Beam Dump: projectile fragmentation case” presentation

http://lise.nscl.msu.edu/work/BeamDump/BeamDump_v1.pdf

- Energy of beam is taken after the production target
  Production target thickness is equal to 30% of range of projectile with energy from the FRIB beam list Reactions
- Initial beam intensity (400 kW) is corrected for reaction lost in the primary production target
- Ti90Al6V4 (1 mm) “beam dump window” is assumed be a target in LISE^{++} file
  Equivalent material (Ti 1.011 mm) for energy loss and atoms number (important for CS) is used in LISE^{++}
- Water (beam dump material) is assumed be a stripper in LISE^{++} file
  “stripper” thickness is equal to difference of projectile ranges in water with energies after the Ti-target and 35 MeV/u correspondingly.