Radiation Residue Calculator

v.9.10.322 from 07/18/16

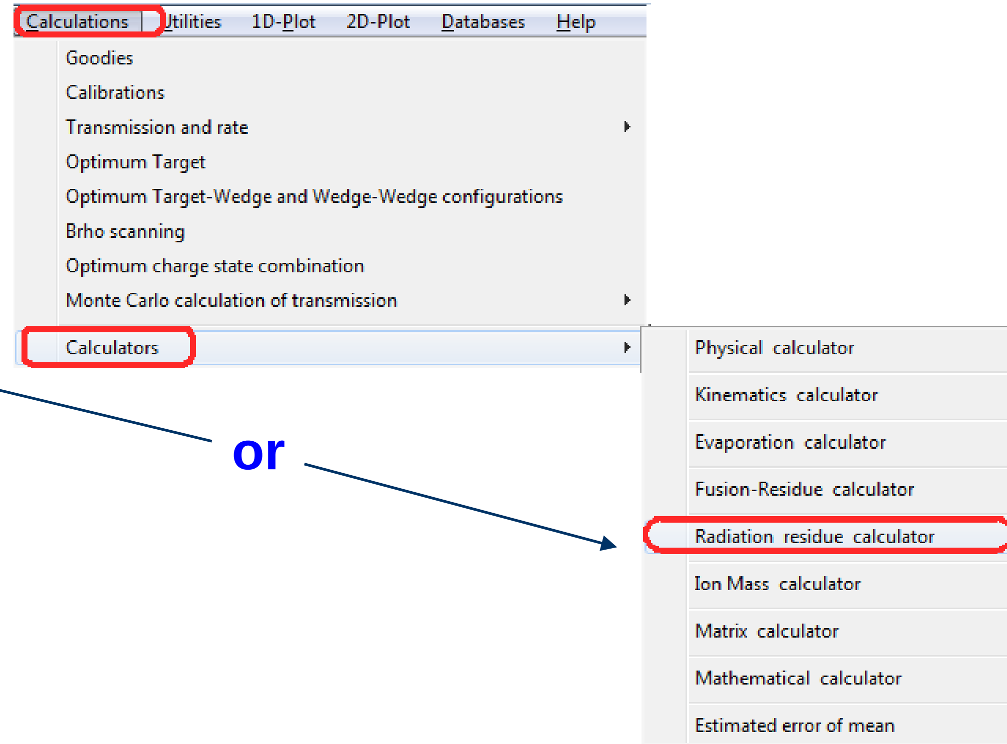
Update v.9.10.332 from 08/01/16

Update v.9.10.372 from 11/01/16

- Introduction
- Modes
- Plots
- Options
- Options : $T_{1/2}$ bounds
- ^{238}U fission case calculation
- ^{229}Th case
- “He-jet” case calculation

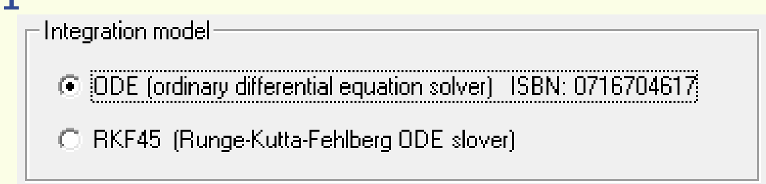
- ^{44}Ti case
- Isotope Production in Beam dump:
  ** Fragmentation case;*
  ** Uranium case*
- “Stiffness” problem
- Using the decay branching ratio database in Radiation Residue calculations
- Final page

Introduction



- About 7300 differential equations
- LISE^{++} uses the AME2012 database for experimental half-lives and internal calculation models for unknown values
- LISE^{++} takes into account two possible decay branches, but the Decay Branch database should be updated

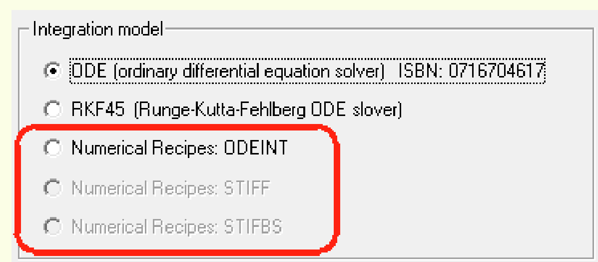
v.1



Lawrence Shampine, Marilyn Gordon,
Computer Solution of Ordinary Differential Equations:
The Initial Value Problem,
Freeman, 1975, ISBN: 0716704617, LC: QA372.S416.

C++ version by John Burkardt

v.2

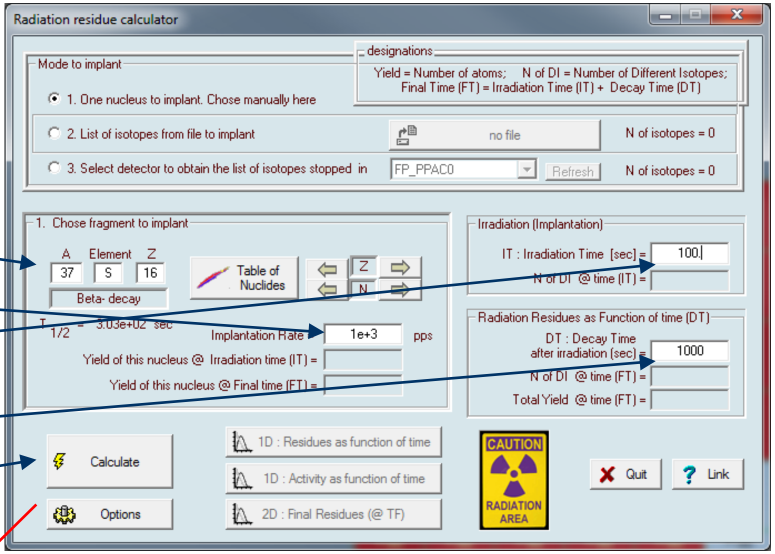


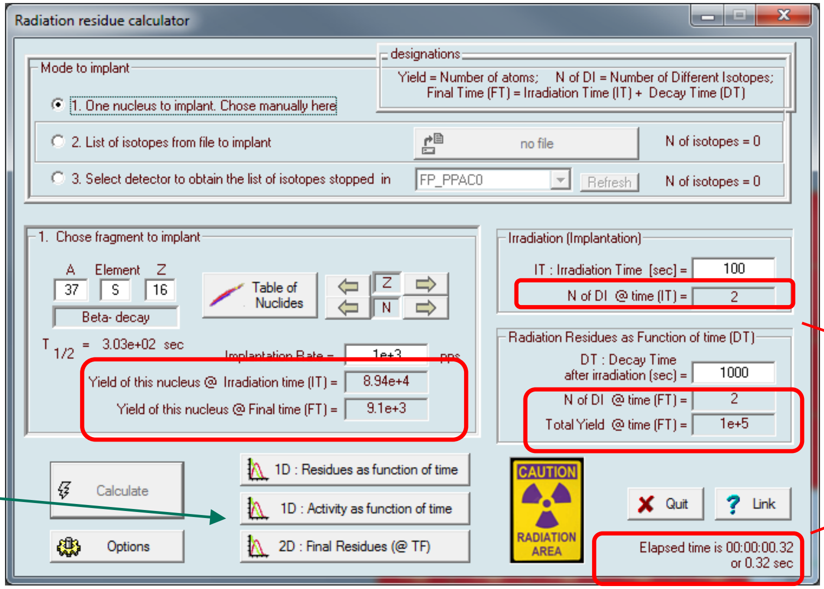
Numerical Recipes in ANSI C++ 2.11

NUMERICAL RECIPES SOFTWARE
P.O. Box 243, Cambridge, MA 02238 (USA)

Modes : One Selected Nucleus

- Select nucleus
- Set irradiation rate
- Set irradiation time
- Set Decay time
- Press button “Calculate”



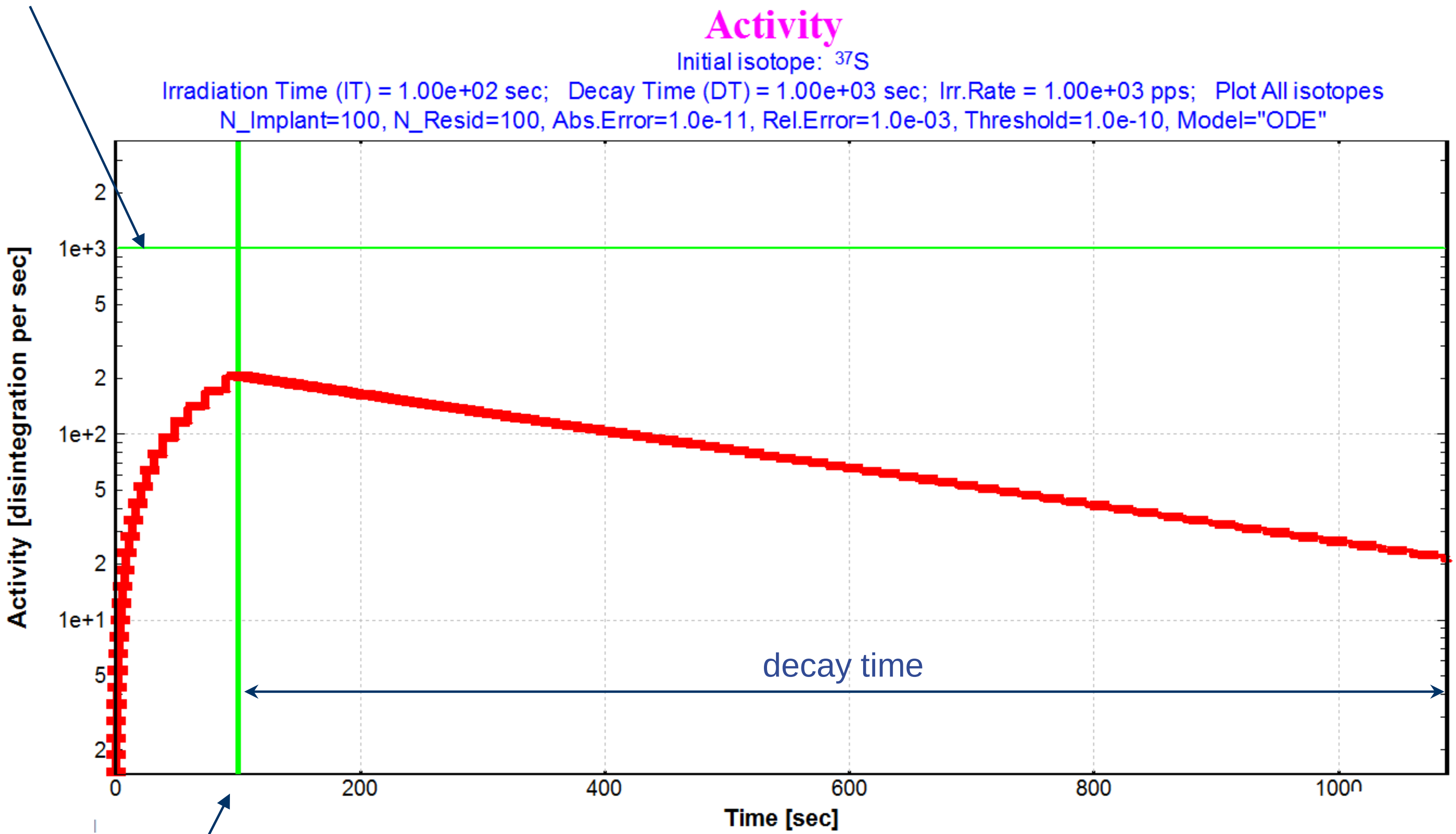


“Plots” buttons became enable

Information about calculation results, and elapsed time

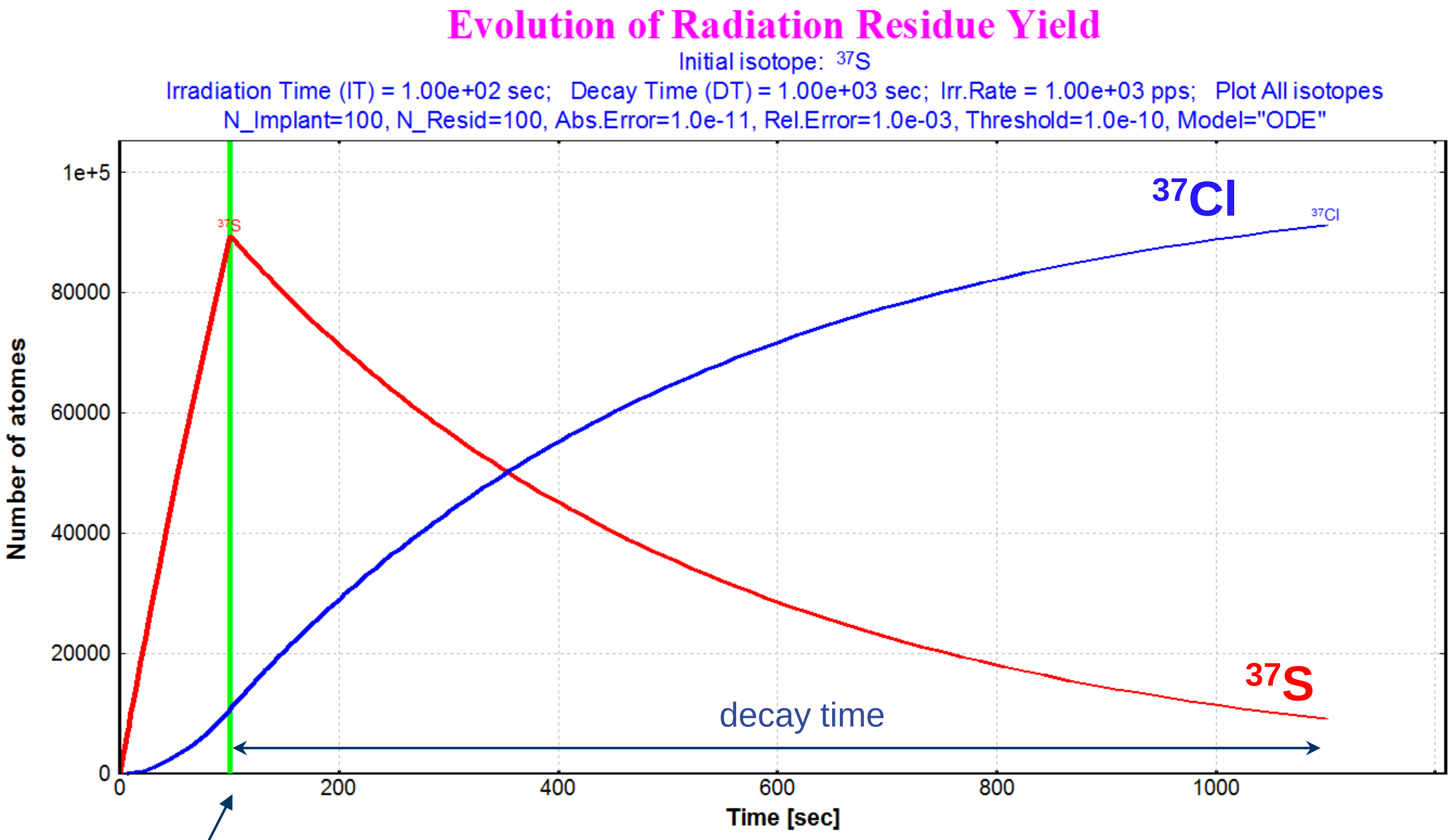
Plots : Activity

This horizontal time shows the irradiation rate



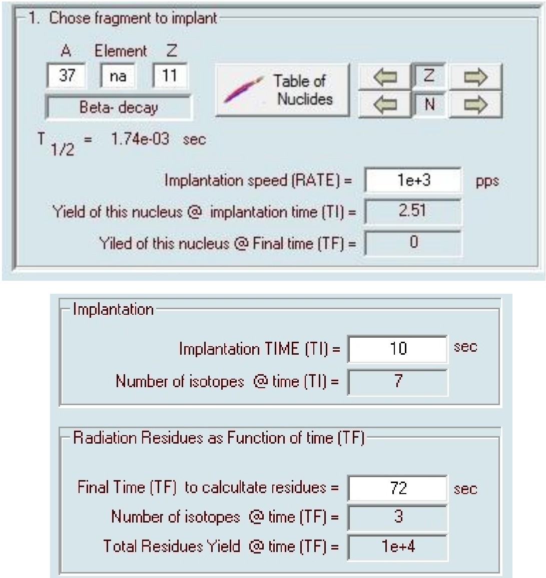
This vertical time shows the irradiation time

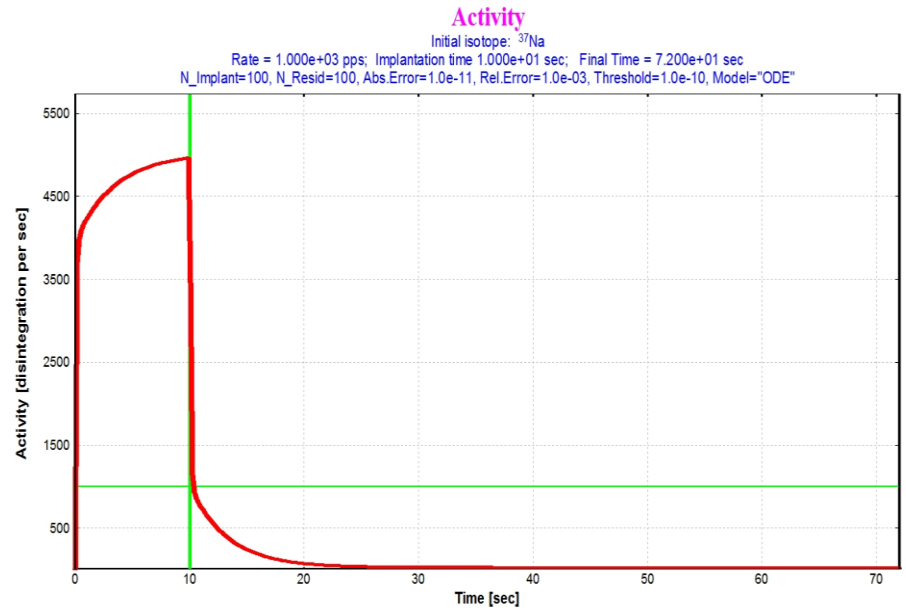
Plots : Evolution of Radiation Residue Yield

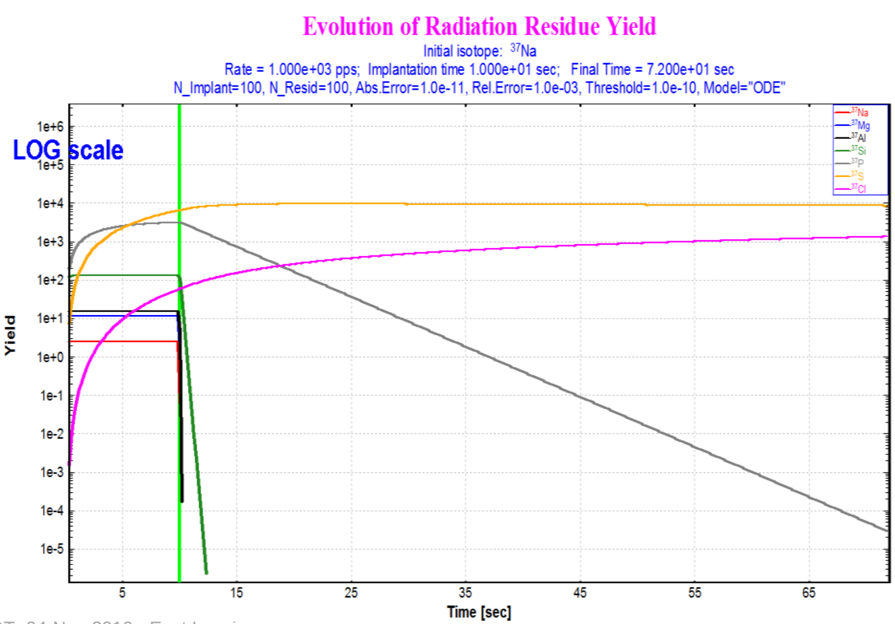


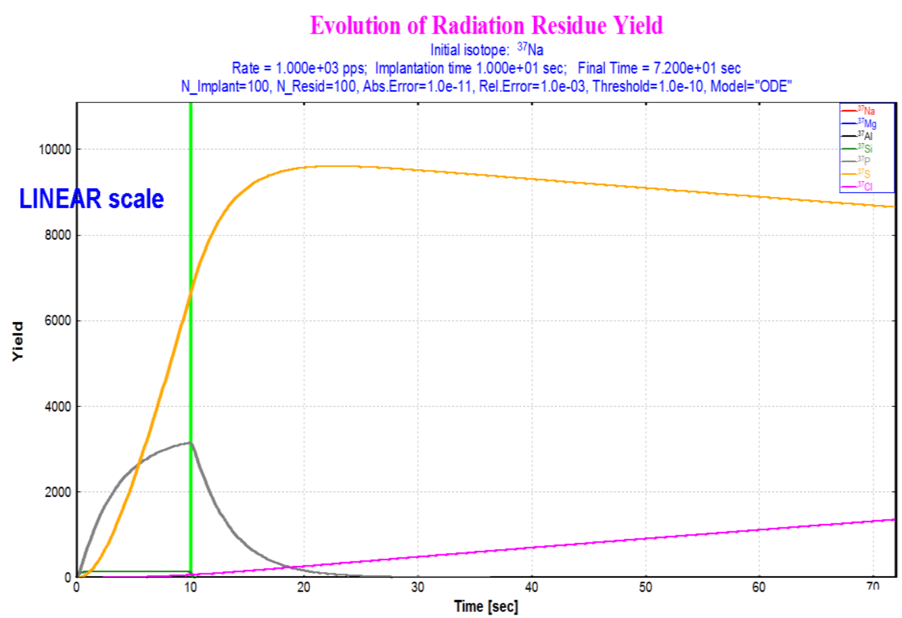
This vertical time shows the irradiation time

Modes : One Selected Nucleus → ^{37}Na example

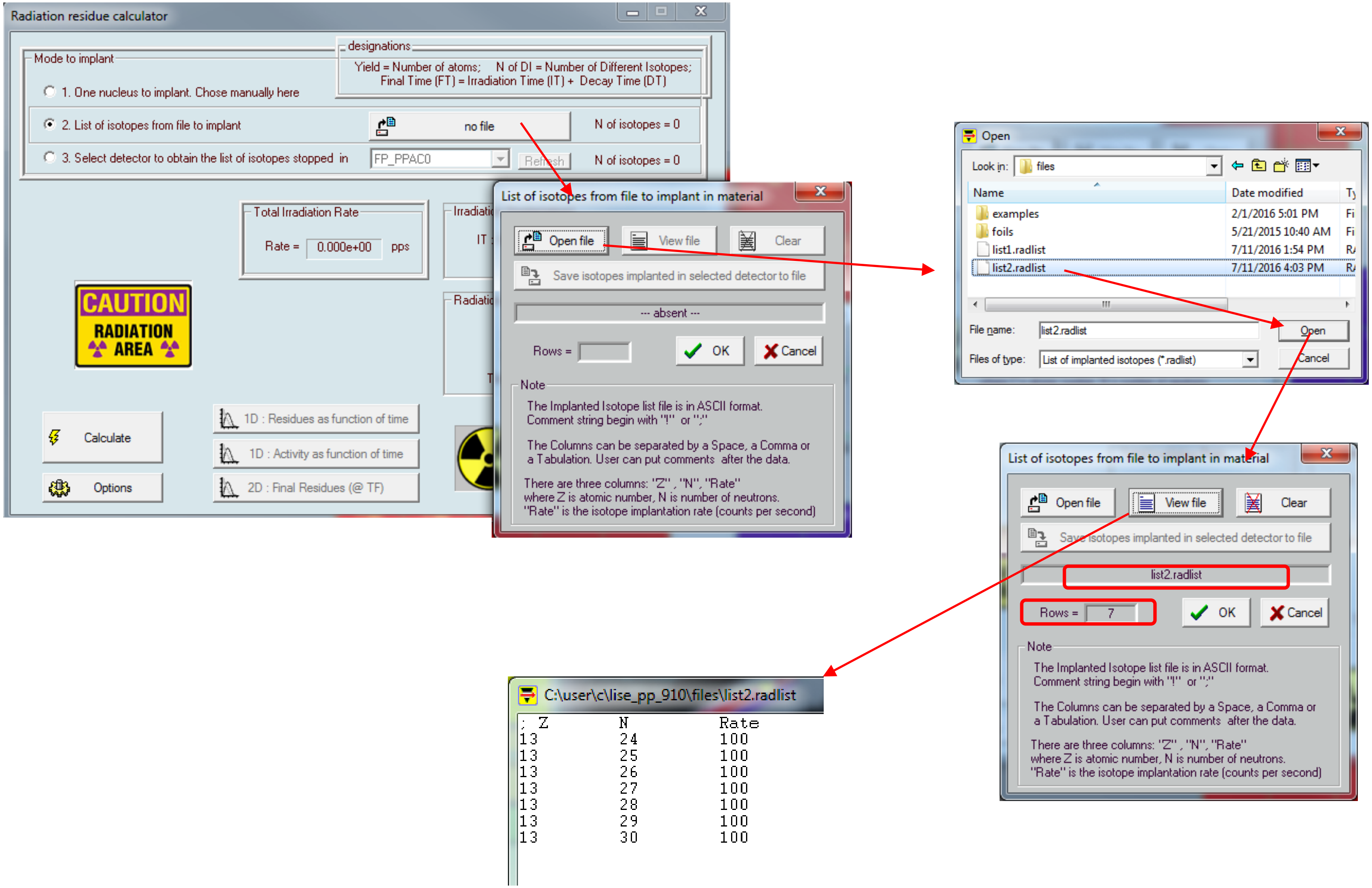






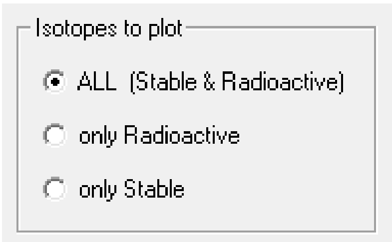


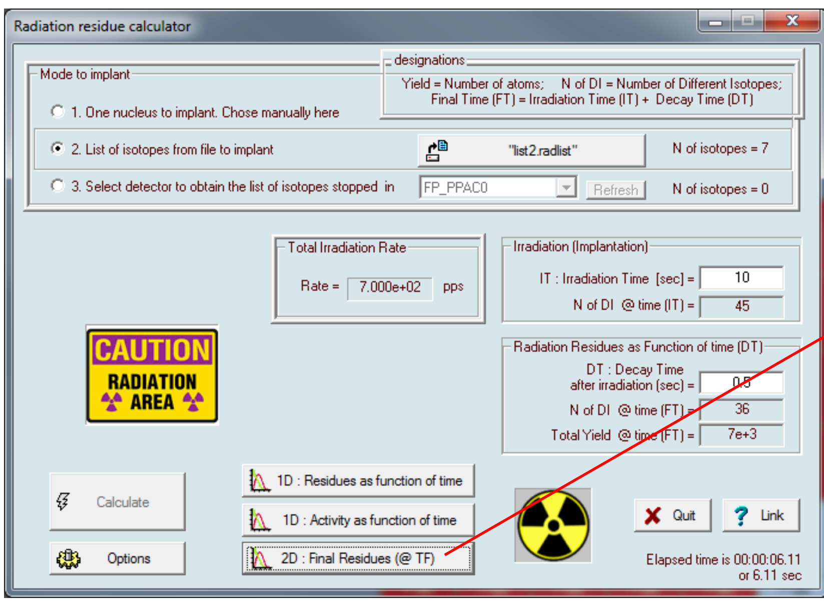
Modes : List of Isotopes to implant from file

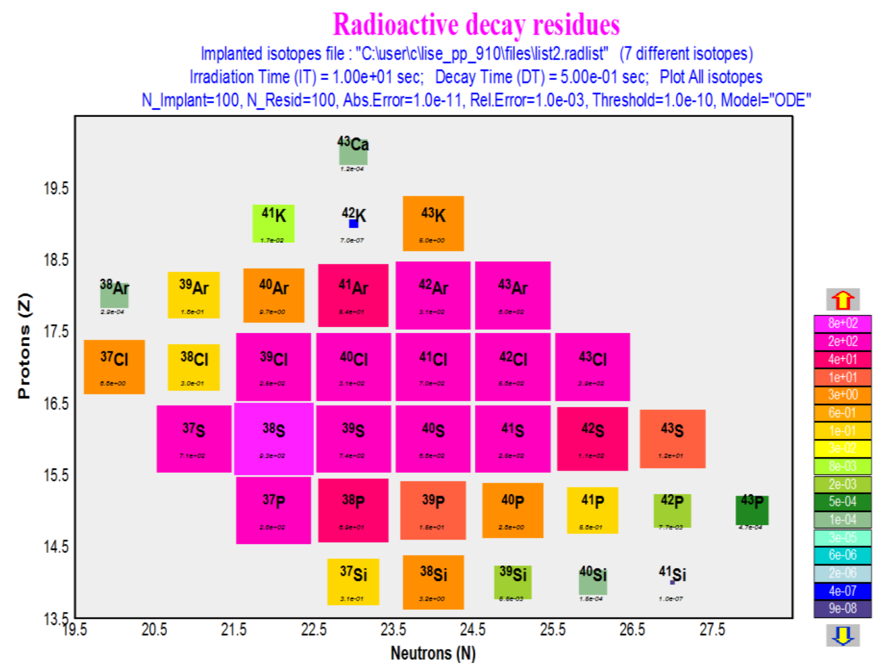


Plots : Final Residues @ FT → Plot All

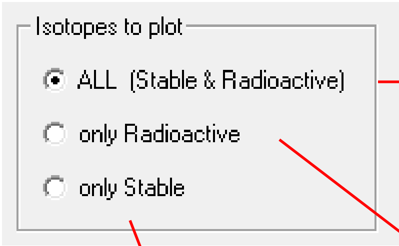
Options

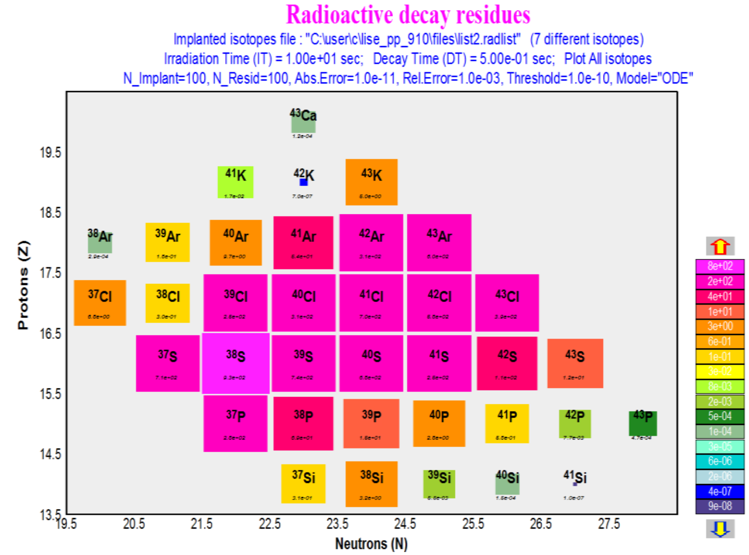


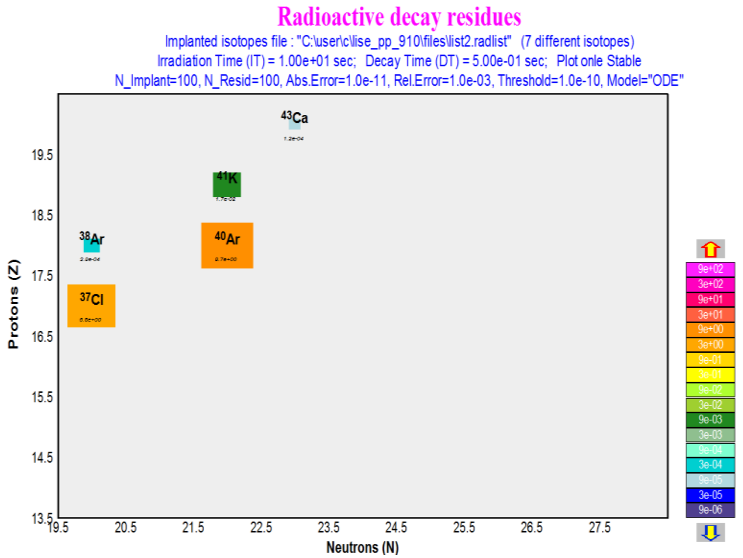


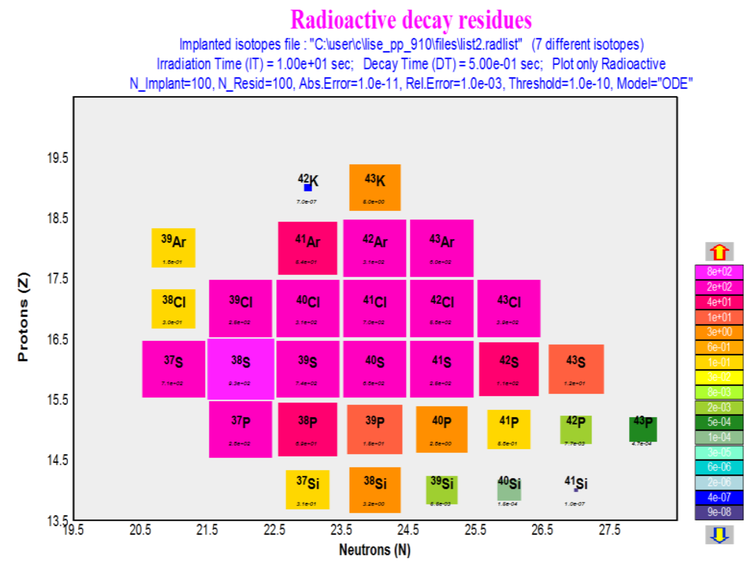


Options


Isotopes to plot
ALL (Stable & Radioactive)
only Radioactive
only Stable

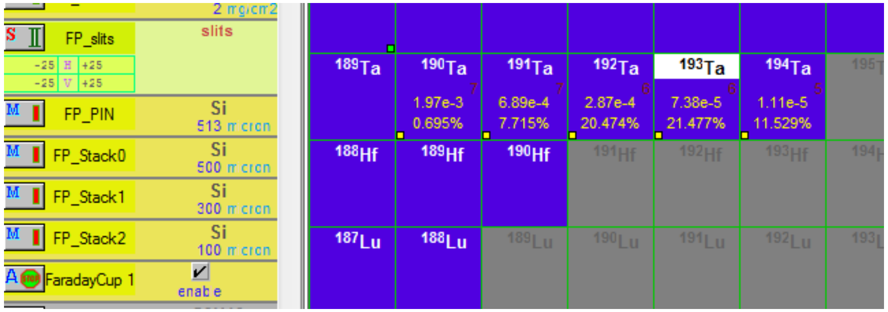

Radioactive decay residues
Implanted isotopes file : "C:\user\c\lise_pp_910\files\list2.radlist" (7 different isotopes)
Irradiation Time (IT) = 1.00e+01 sec; Decay Time (DT) = 5.00e-01 sec; Plot All isotopes
N_Implant=100, N_Resid=100, Abs.Error=1.0e-11, Rel.Error=1.0e-03, Threshold=1.0e-10, Model="ODE"
Protons (Z)
Neutrons (N)
43Ca
41K 42K 43K
38Ar 39Ar 40Ar 41Ar 42Ar 43Ar
37Cl 38Cl 39Cl 40Cl 41Cl 42Cl 43Cl
37S 38S 39S 40S 41S 42S 43S
37P 38P 39P 40P 41P 42P 43P
37Si 38Si 39Si 40Si 41Si

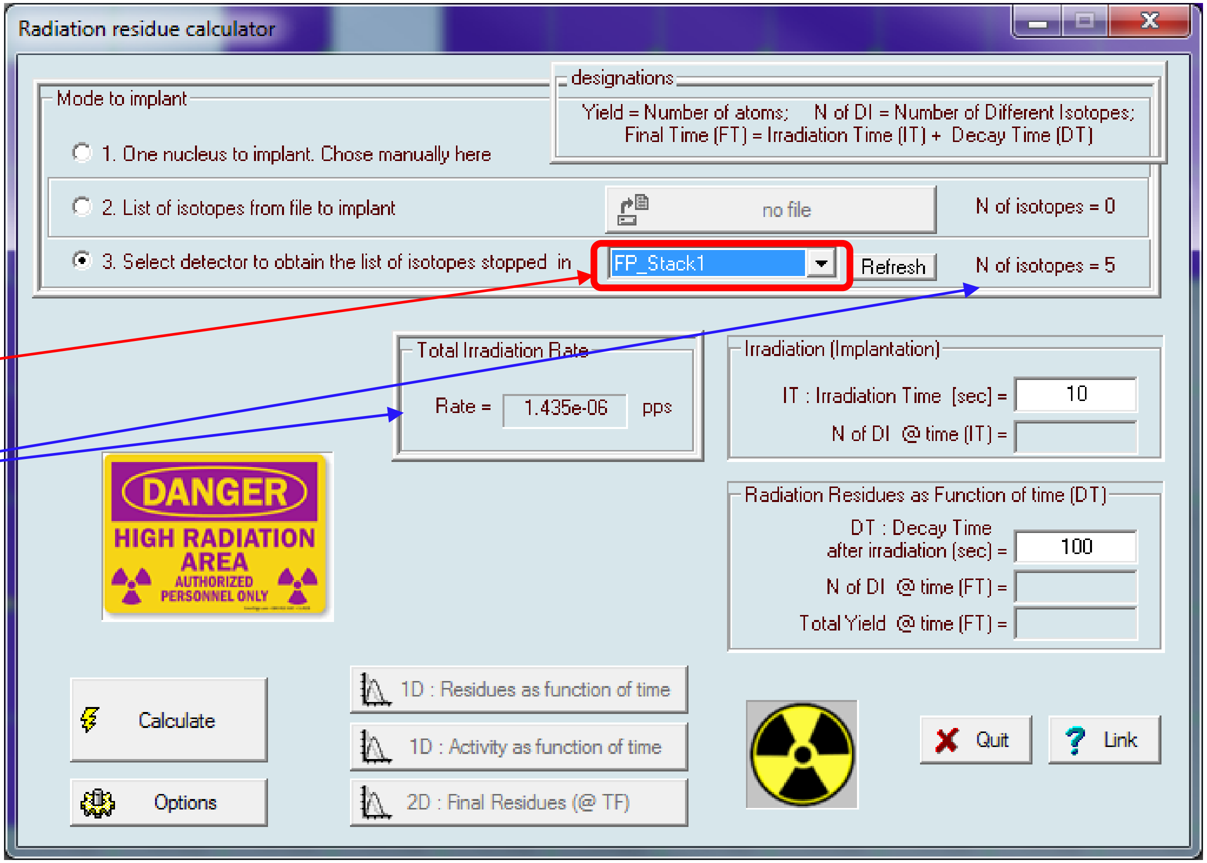

Radioactive decay residues
Implanted isotopes file : "C:\user\c\lise_pp_910\files\list2.radlist" (7 different isotopes)
Irradiation Time (IT) = 1.00e+01 sec; Decay Time (DT) = 5.00e-01 sec; Plot onle Stable
N_Implant=100, N_Resid=100, Abs.Error=1.0e-11, Rel.Error=1.0e-03, Threshold=1.0e-10, Model="ODE"
Protons (Z)
Neutrons (N)
43Ca
41K
38Ar 40Ar
37Cl


Radioactive decay residues
Implanted isotopes file : "C:\user\c\lise_pp_910\files\list2.radlist" (7 different isotopes)
Irradiation Time (IT) = 1.00e+01 sec; Decay Time (DT) = 5.00e-01 sec; Plot only Radioactive
N_Implant=100, N_Resid=100, Abs.Error=1.0e-11, Rel.Error=1.0e-03, Threshold=1.0e-10, Model="ODE"
Protons (Z)
Neutrons (N)
42K 43K
39Ar 41Ar 42Ar 43Ar
38Cl 39Cl 40Cl 41Cl 42Cl 43Cl
37S 38S 39S 40S 41S 42S 43S
37P 38P 39P 40P 41P 42P 43P
37Si 38Si 39Si 40Si 41Si

Modes : List of Isotopes from DETECTOR

File: http://lise.nscl.msu.edu/9_10/radiation/test_radiation.lpp

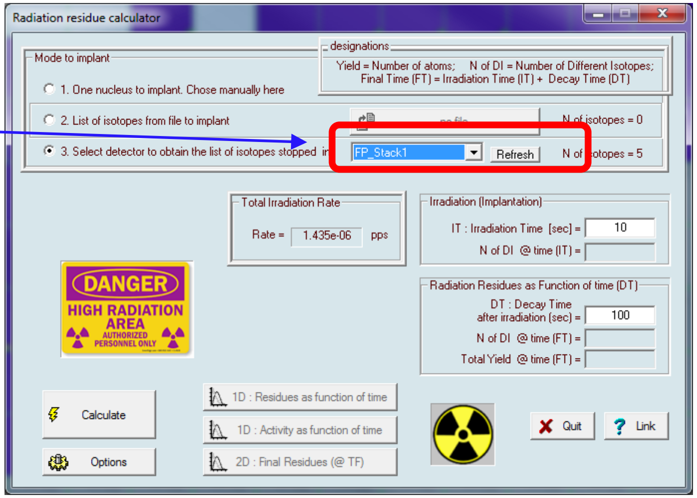




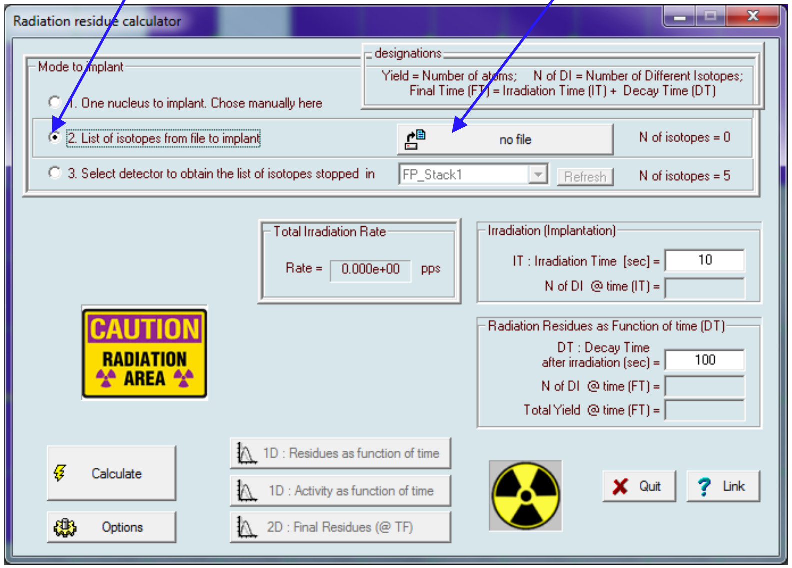
Select detector where some isotopes stopped

Modes : List of Isotopes from DETECTOR → save to file

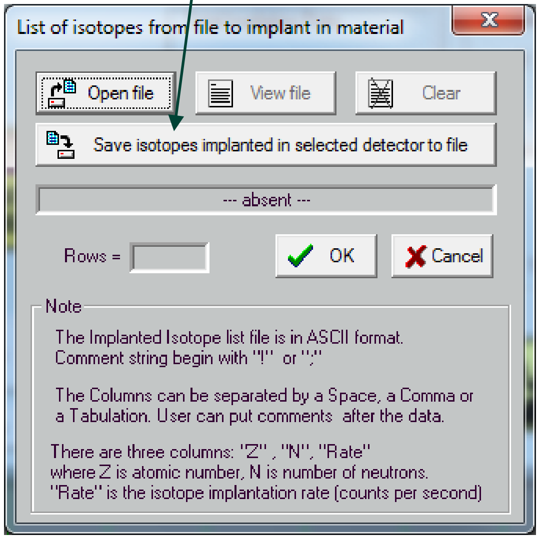
1. Select detector where some isotopes stopped



2. Chose the mode "List of isotope to implant" and then click the "File" button

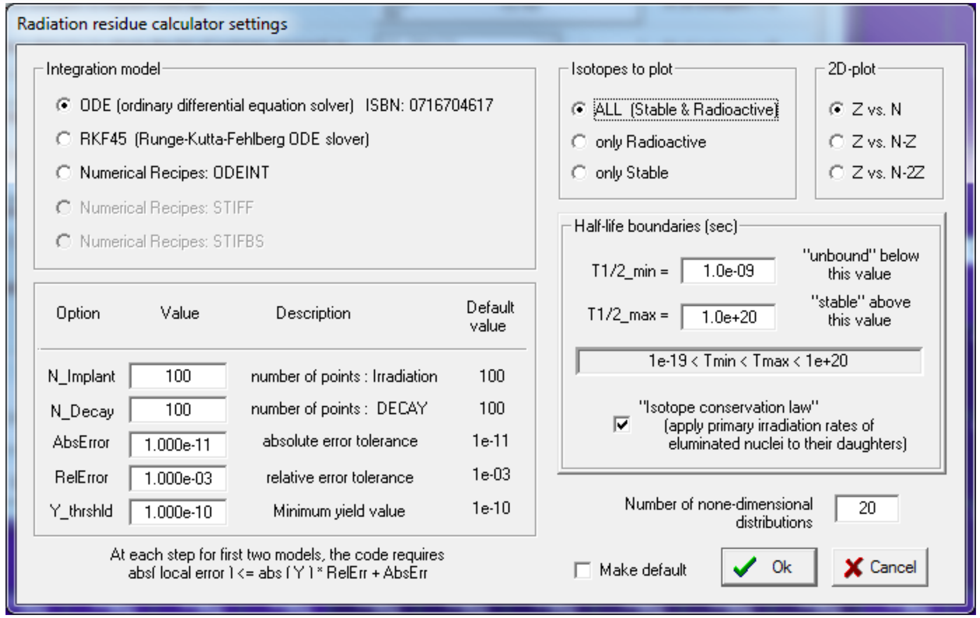


3. Save isotopes to file



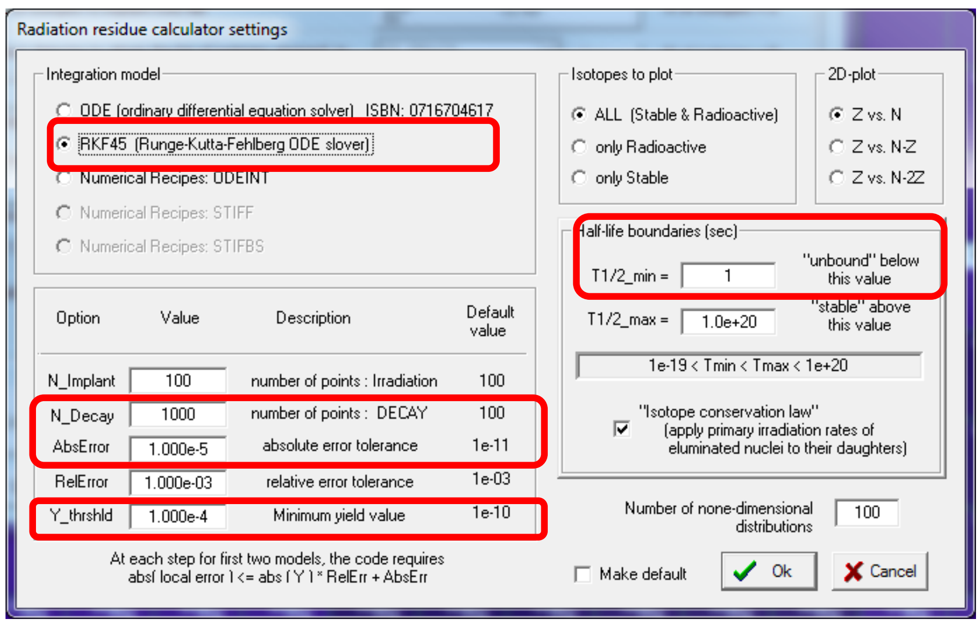
Options

default



For HUGE decay time (years)

Try to keep “AbsError” value (used in ODE) smaller than Y_thrshld (minimum yield value used in LISE^{++} Radiation class)



Options : $T_{1/2}$ bounds

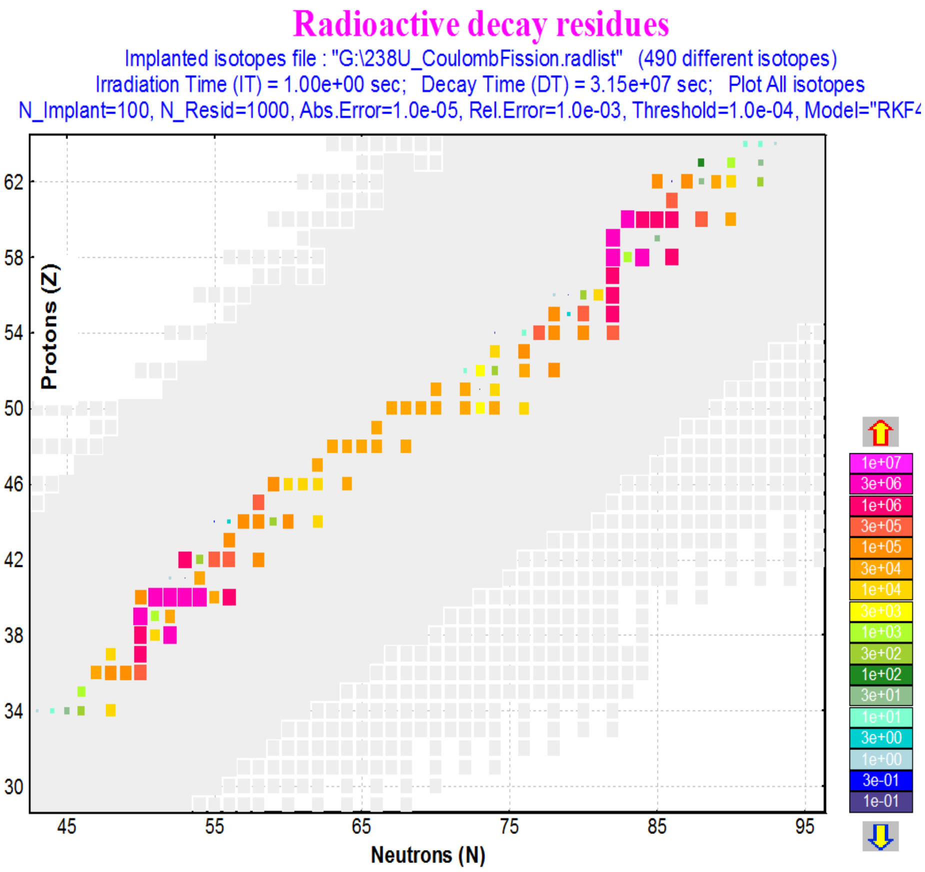
http://lise.nscl.msu.edu/9_10/radiation/RadResCalc_v2a.pdf

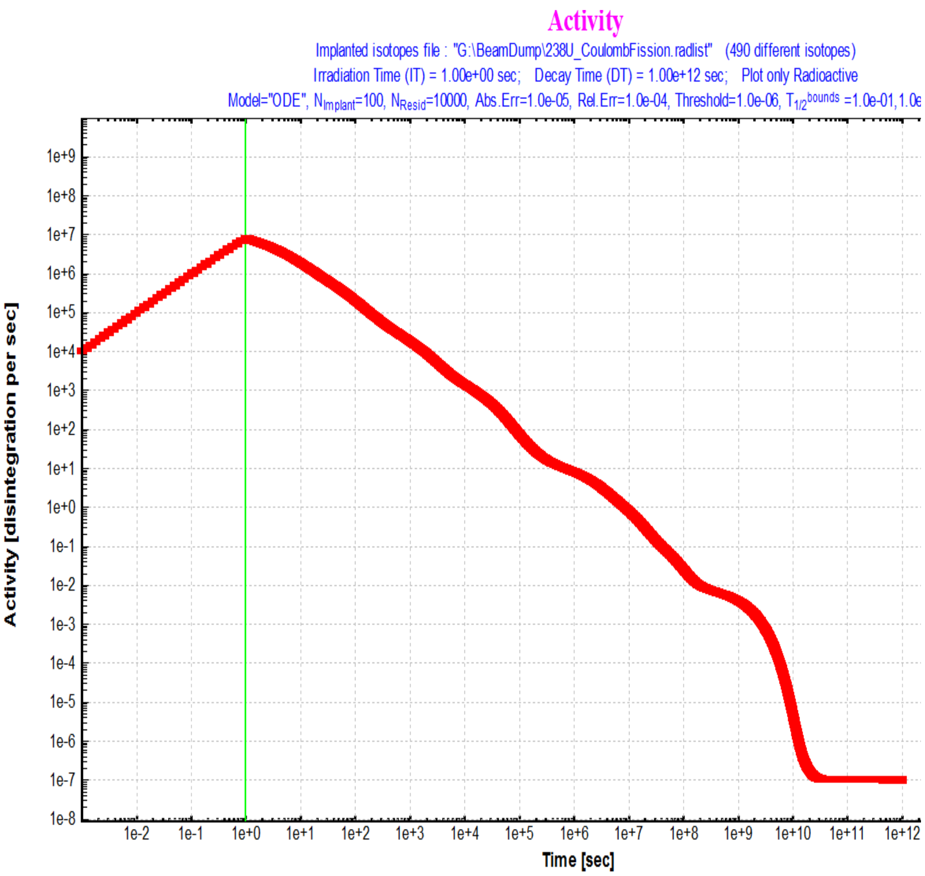
Radiation Residues Calculator : $T_{1/2}$ bounds

- New $T_{1/2}$ boundaries options
- ^{221}U irradiation case
- ^{238}U @ FRIB Beam Dump & $T_{1/2}$ boundaries options

Version 2 : **http://lise.nscl.msu.edu/9_10/radiation/RadiationResidue_U2.pdf**

Version 1 : http://lise.nscl.msu.edu/9_10/radiation/RadiationResidue_U1.pdf

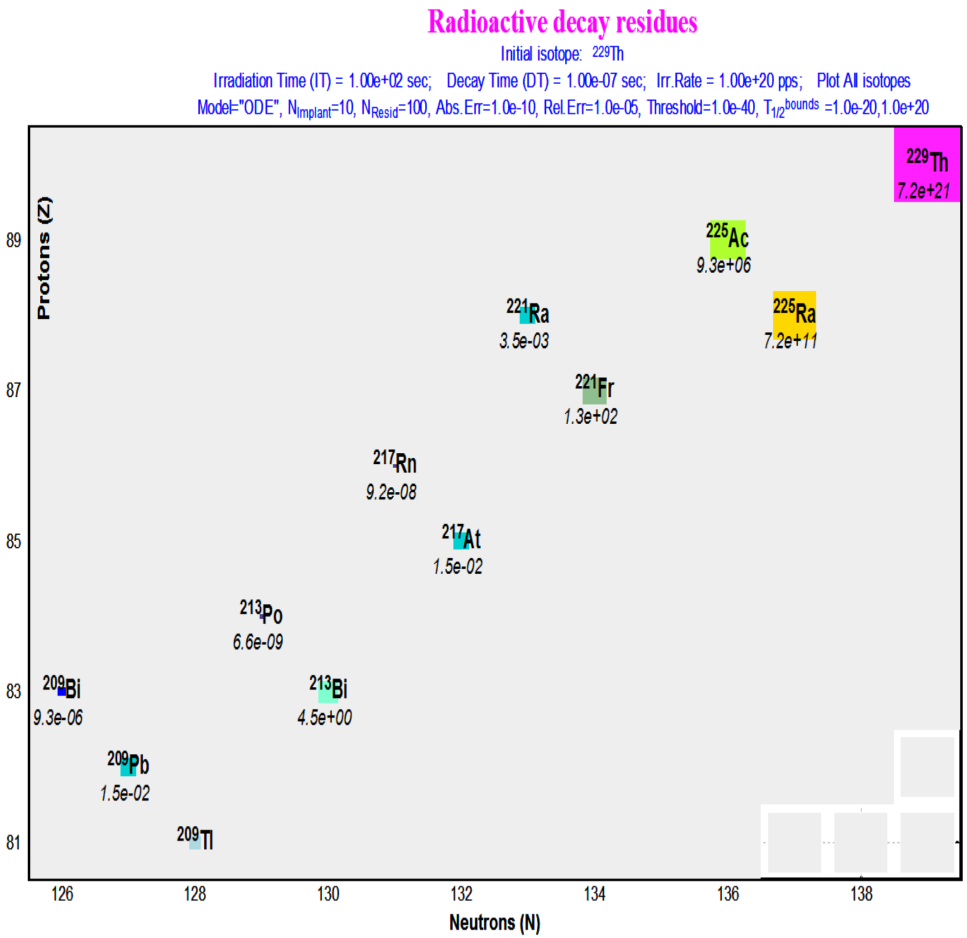


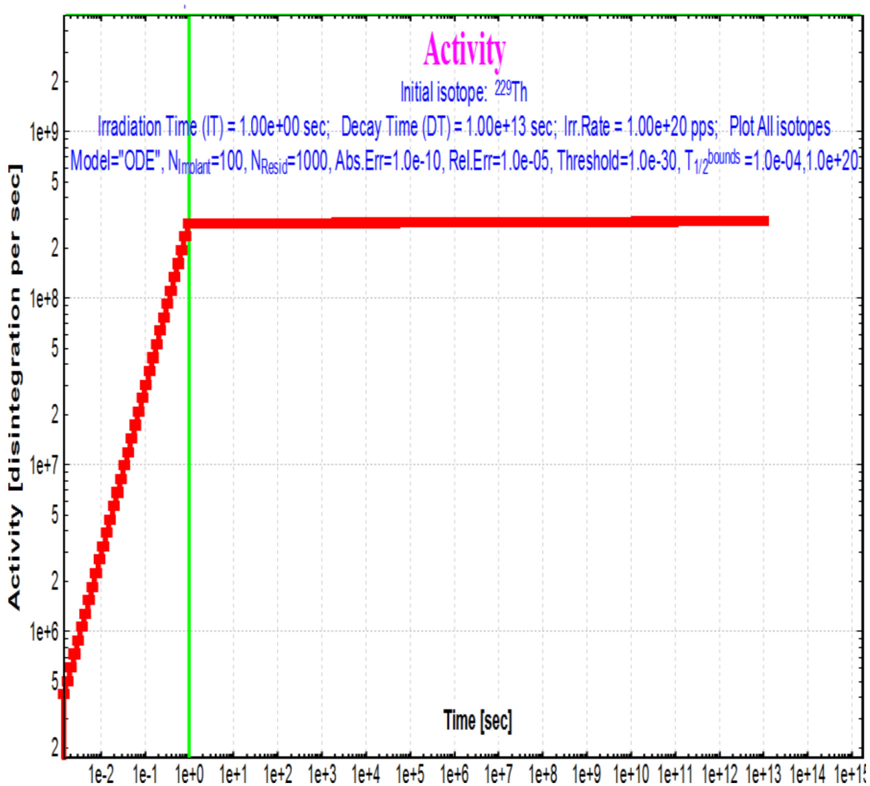


^{229}Th case

Version 2 : **http://lise.nscl.msu.edu/9_10/radiation/RadiationResidue_229Th_v2.pdf**

Version 1 : http://lise.nscl.msu.edu/9_10/radiation/RadiationResidue_229Th_v1.pdf

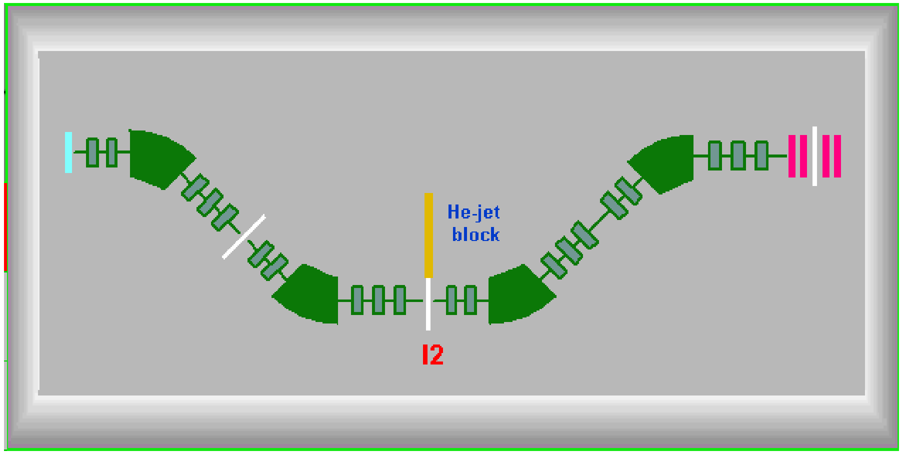




"He-jet" case calculation

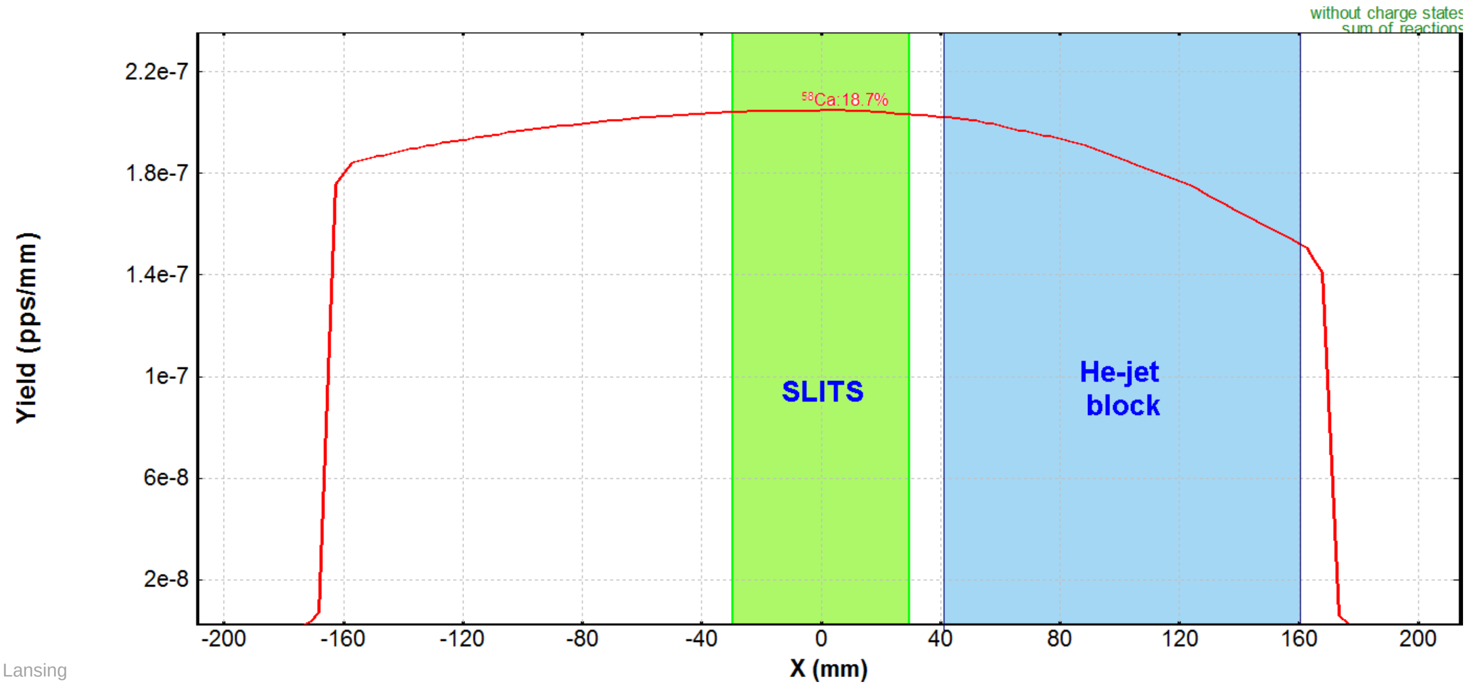
Assume the production ^{58}Ca from using the ^{82}Se beam with the A1900 fragment separator, and the He-jet block located at 40-160 mm (I2 position)

File: **http://lise.nscl.msu.edu/9_10/radiation/82Se_58Ca.lpp**



I2_slits-Xspace: output before slits

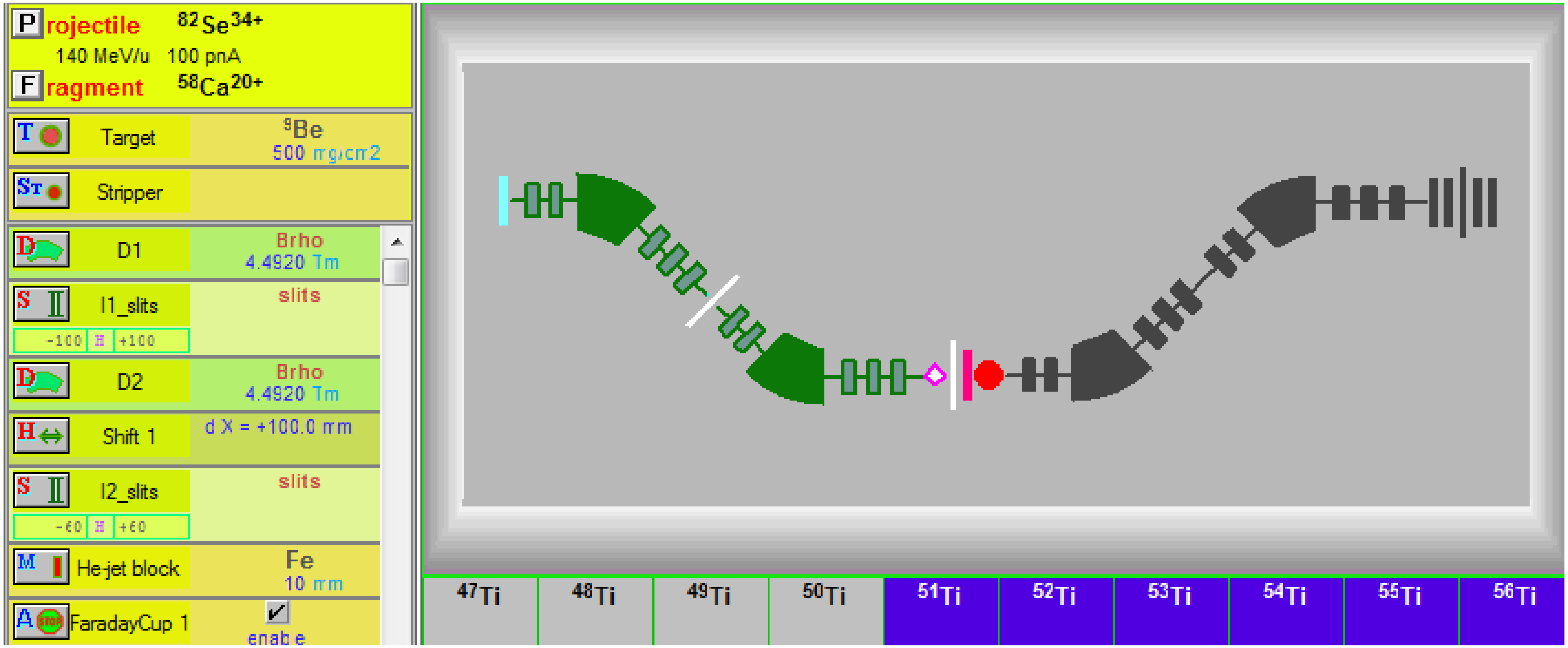
^{82}Se (140 MeV/u) + Be (500 mg/cm^2); Settings on ^{58}Ca; Config: DSDSWDDMMSMM
dp/p=1.00% ; Wedges: 0; Brho(Tm): 4.4920, 4.4920, 4.4920, 4.4920



Steps to create the “He-jet” configuration from previous case:

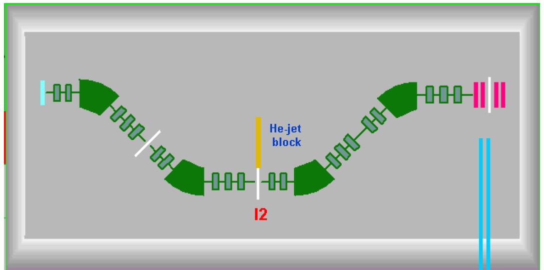
1. Set Width of I2 slits equal to the He-jet block width (+/- 60 mm)
2. Behind the I2 slits insert a thick material enough to stop all products
3. After this material set the Faraday cup
4. Insert the shift block dX=100 mm in front of the I2 slits, assuming the central axis is passing through the center of He-jet block

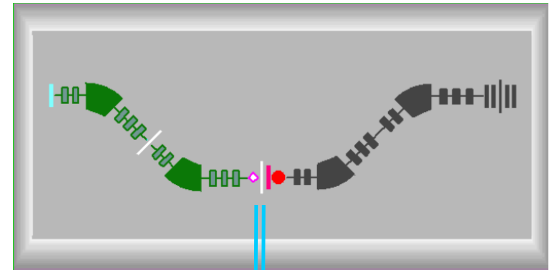
File: http://lise.nscl.msu.edu/9_10/radiation/82Se_58Ca_He-jet.lpp



“He-jet” case calculation

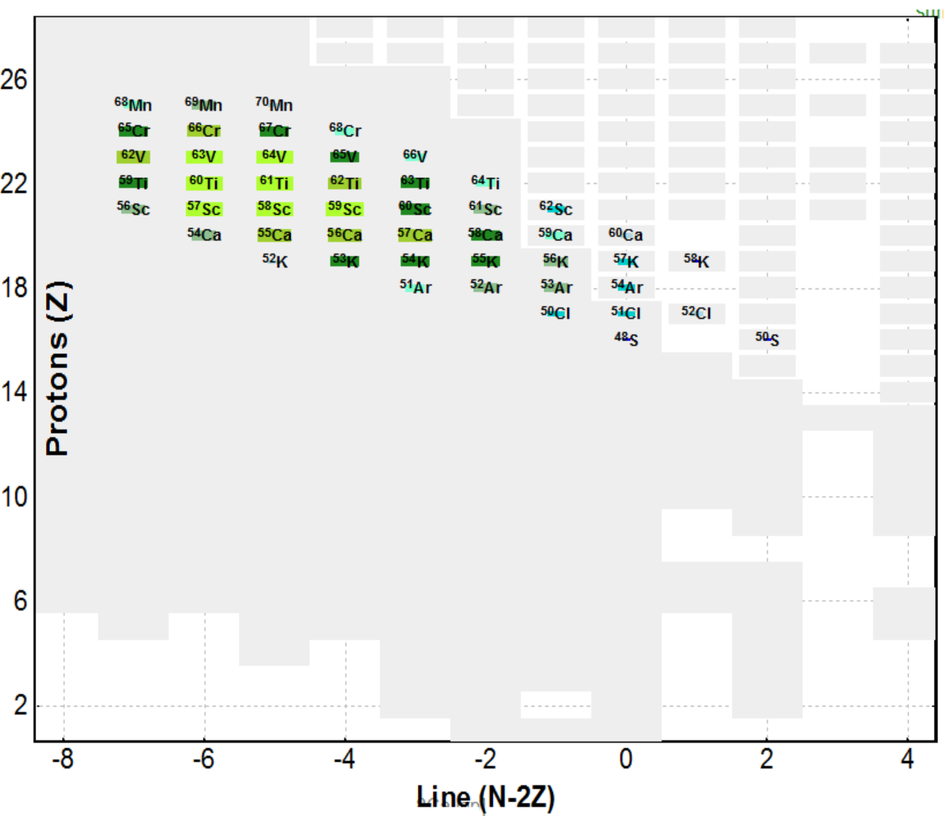
82Se_58Ca.lpp	82Se_58Ca_He-jet.lpp

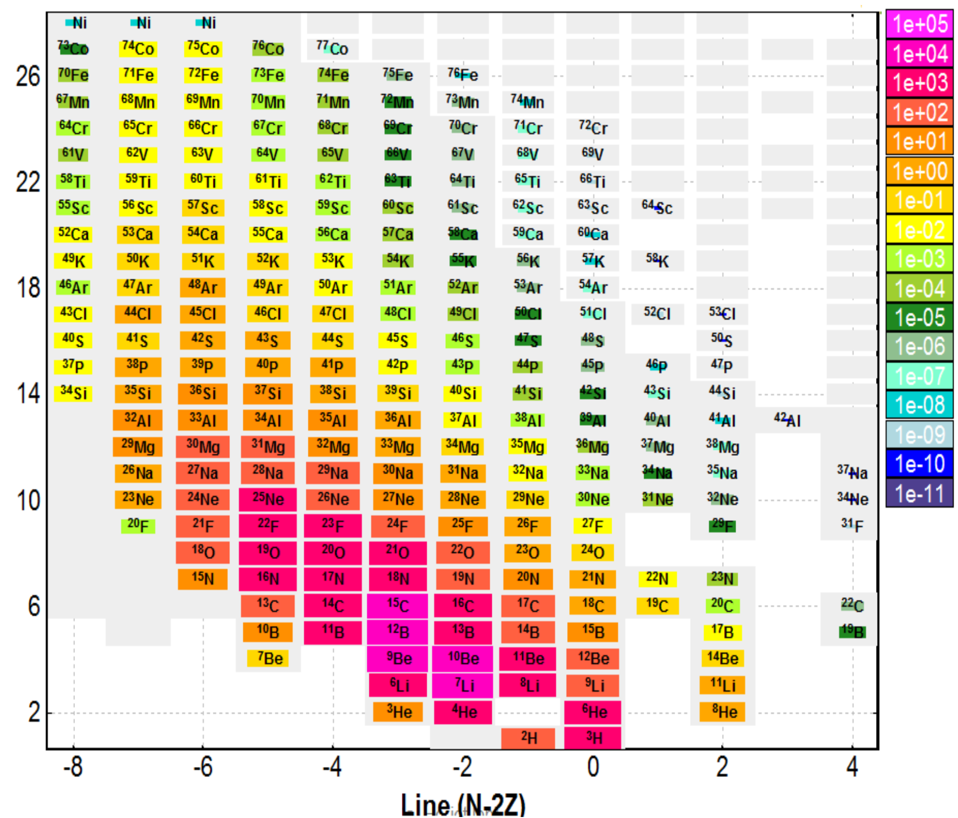




Rate 0.02 pps

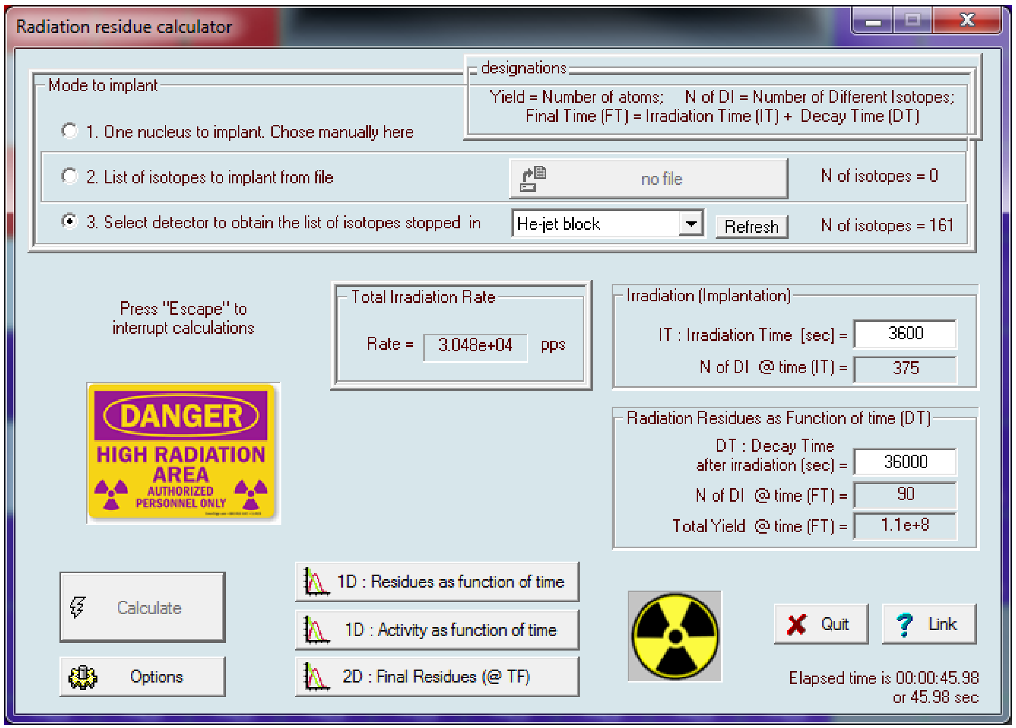
Rate 1.6e5 pps

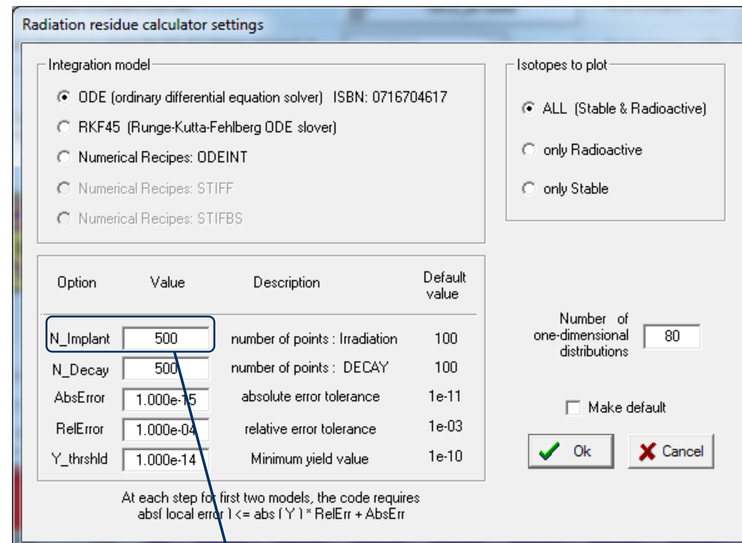




“He-jet” case calculation

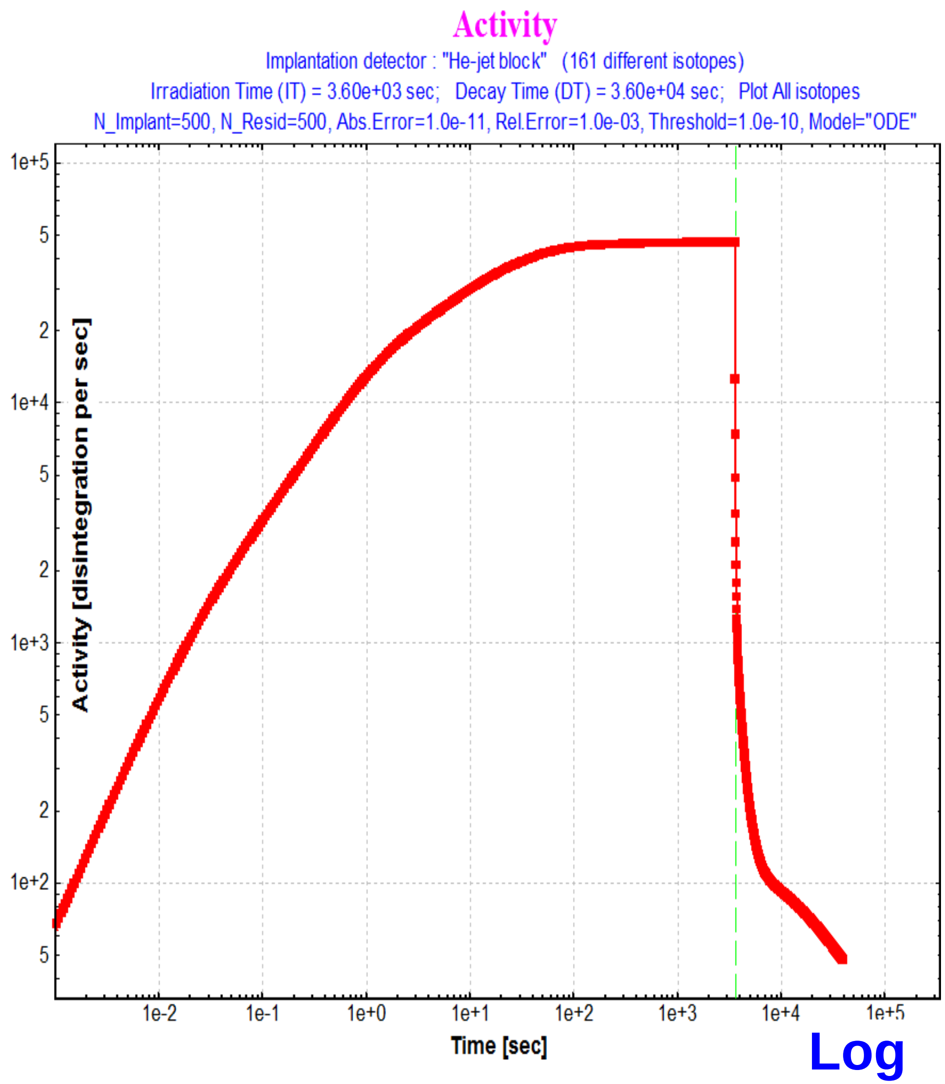
1. Calculate all products with new 82Se_58Ca_He-jet.lpp file
2. Call the Radiation Residue Calculator
3. Set the Irradiation and Detector times (for example 1 & 10 hours)
4. Chose “He-jet block” as detector
5. Click the “Calculation” button

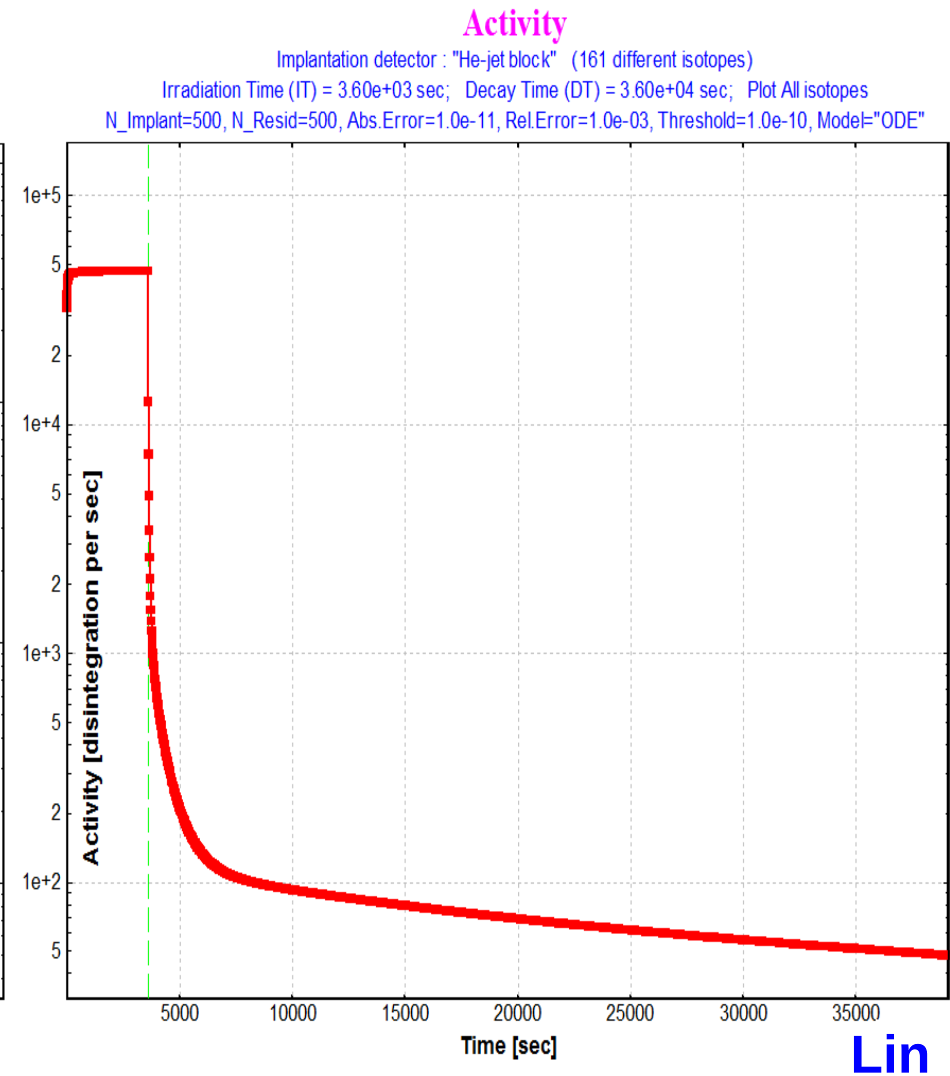




Maximum number of iterations (50000) has been reached for N_implantation=100 for two last implantation steps

“He-jet” case calculation : Activity





"He-jet" case calculation : Final residue products

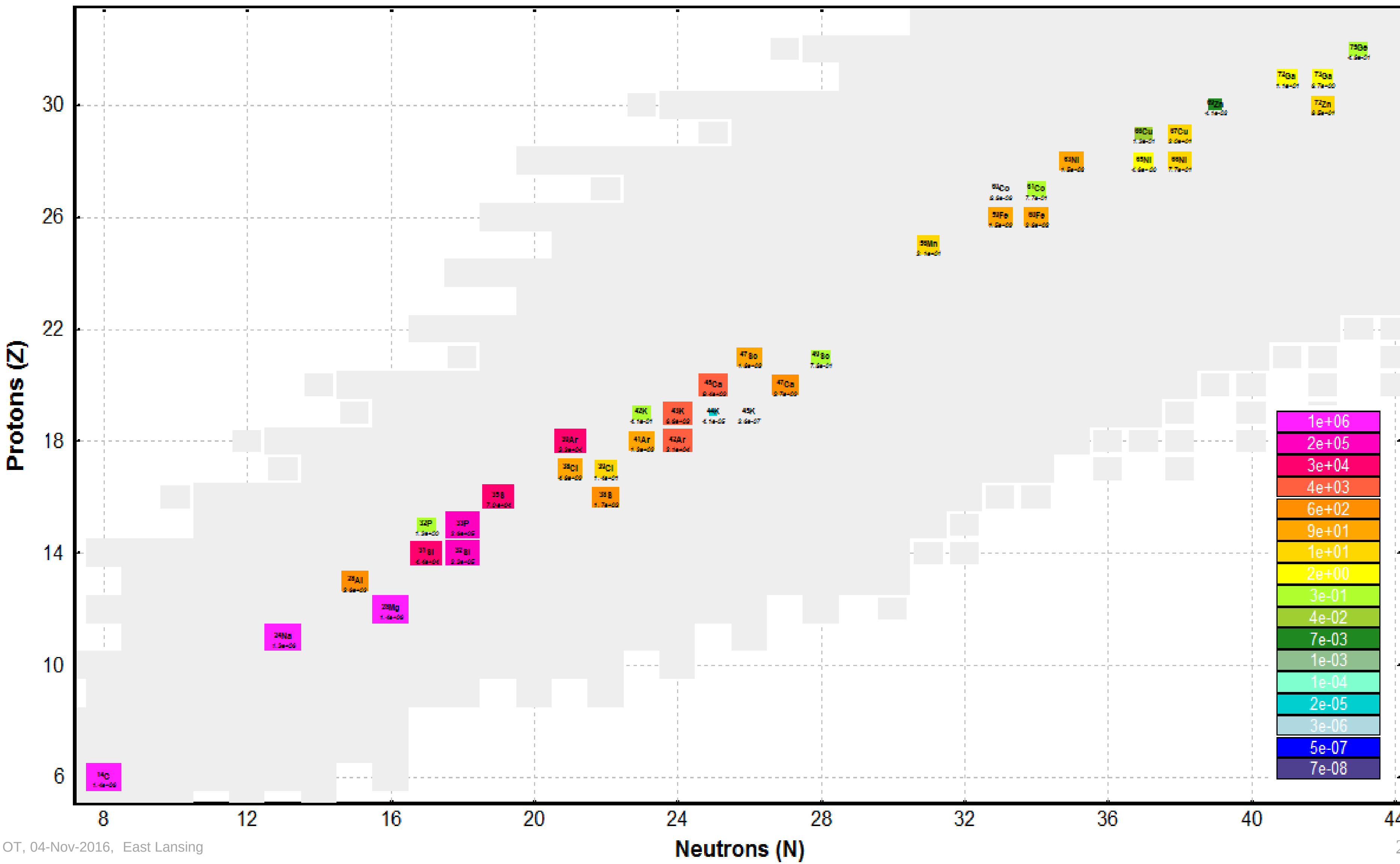
Only radioactive residues

Radioactive decay residues

Implantation detector : "He-jet block" (161 different isotopes)

Irradiation Time (IT) = 3.60e+03 sec; Decay Time (DT) = 3.60e+04 sec; Plot only Radioactive

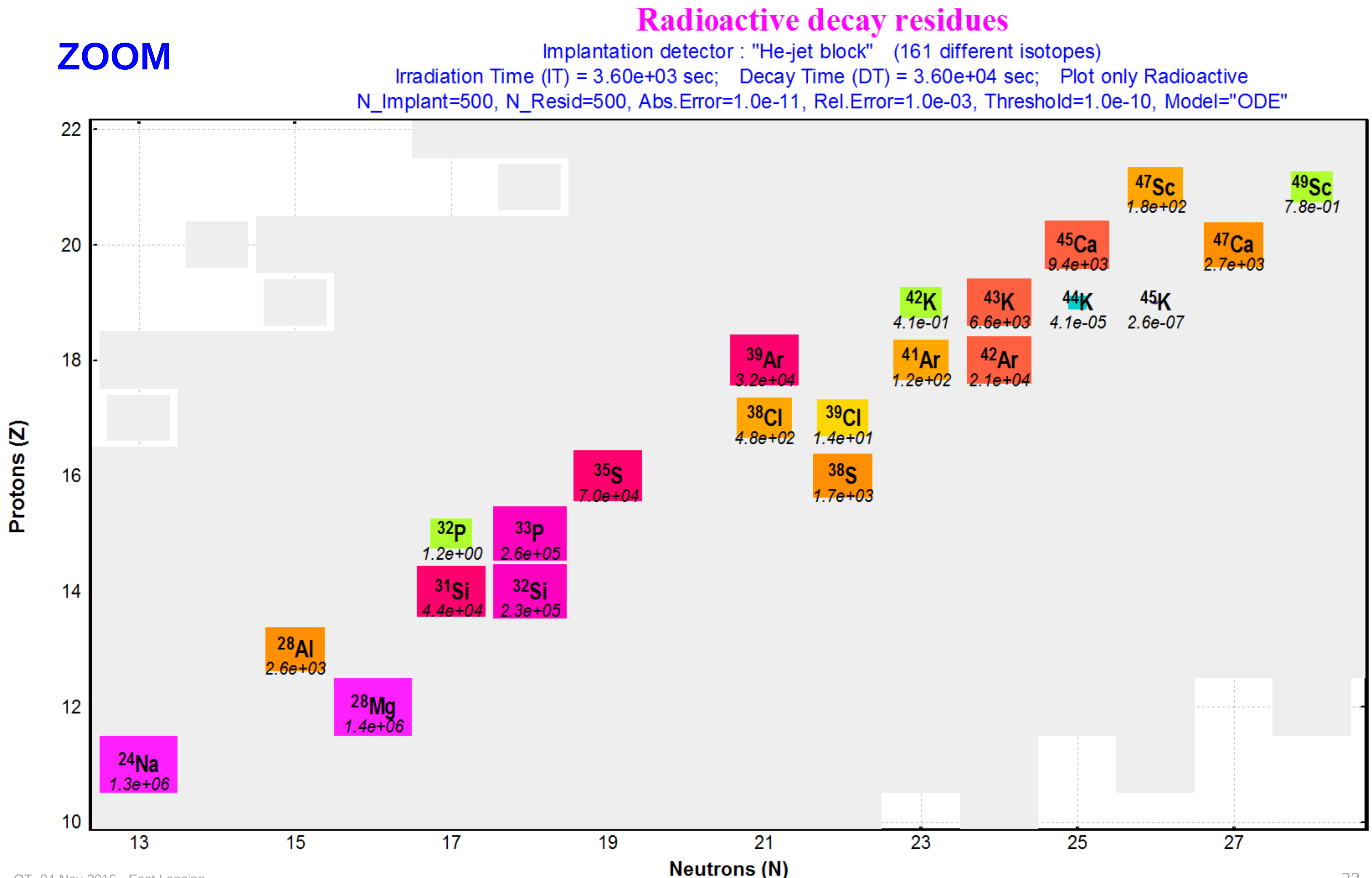
N_Implant=500, N_Resid=500, Abs.Error=1.0e-11, Rel.Error=1.0e-03, Threshold=1.0e-10, Model="ODE"



"He-jet" case calculation : Final residue products

Only radioactive residues

ZOOM



^{44}Ti's case

http://lise.nscl.msu.edu/9_10/radiation/RadiationResidue_44Ti.pdf

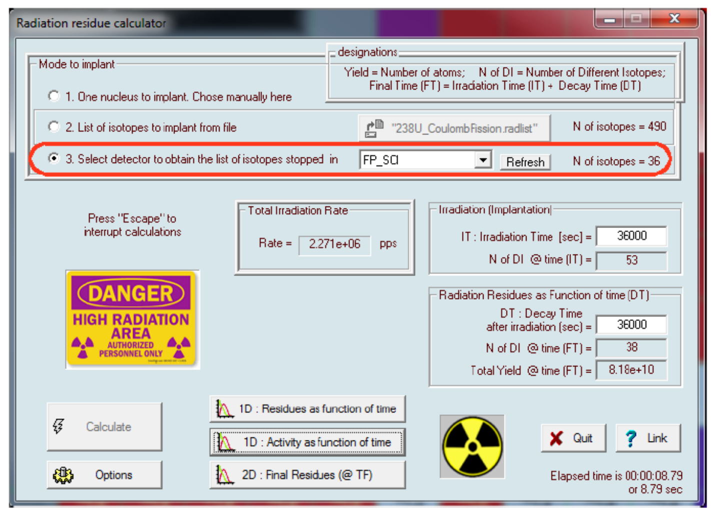
Radiation Residue Calculator : ^{44}Ti

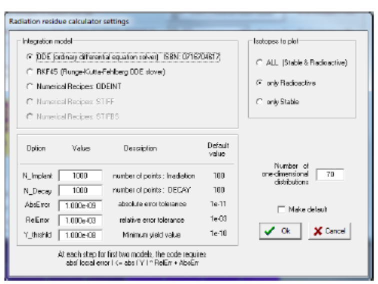
v.9.10.341
from 08/05/16

http://lise.nscl.msu.edu/9_10/radiation/44Ti%20from%2058Ni.lpp

Table 1. Priority isotopes for harvesting at FRIB. These isotopes were identified at the Working Group meeting in Santa Fe, NM September 30 – October 1, 2010.

Isotope	Half-life	Application
^{32}Si	160 y	Tracer; geology and botany
^{44}Ti	60 y	Medicine, astrophysics, nuclear structure
^{48}V	16 d	Stockpile Stewardship
^{67}Cu	2.6 d	Medicine
^{85}Kr	10.0 d	Astrophysics, stockpile stewardship
Eu*		Stockpile Stewardship
^{211}Rn	14.6 h	Medicine
^{225}Ra	14.9d	Medicine, Electric Dipole Moment
^{225}Ac	10.0 d	Medicine



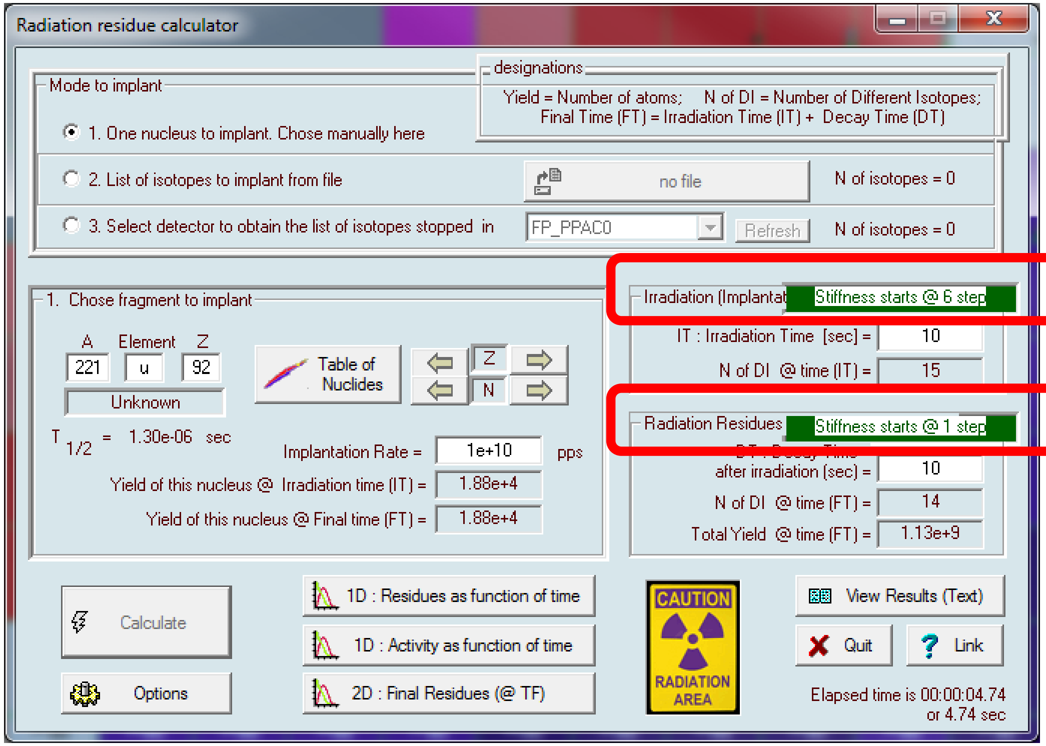


OT, 08-Aug-2016, East Lansing

1

http://lise.nscl.msu.edu/9_10/radiation/RadiationResidueStiff.pdf

[In mathematics, a stiff equation](#) is a differential equation for which certain numerical methods for solving the equation are numerically unstable, unless the step size is taken to be extremely small. It has proven difficult to formulate a precise definition of stiffness, but the main idea is that the equation includes some terms that can lead to rapid variation in the solution.



Isotope Production in Beam dump: Fragmentation case

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

Isotope Production in the FRIB Beam Dump : projectile fragmentation case

- Manual "step-by-step" table with initial beam & target settings
- Production settings
- Energy, Intensity, Thickness
- Radiation residues calculator
- Equivalent material and thickness
- Next steps

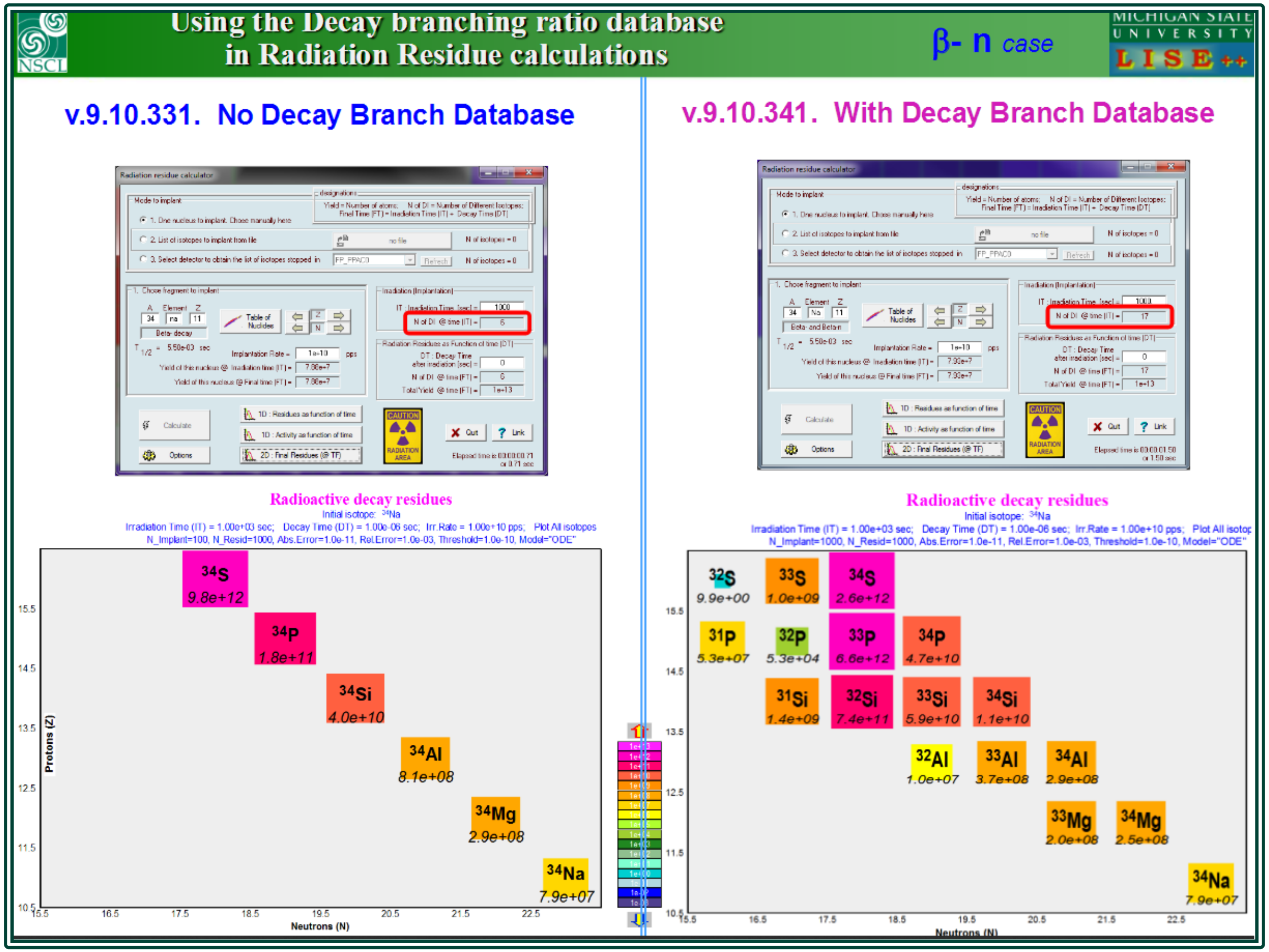
http://lise.nscl.msu.edu/work/BeamDump/BeamDumpUranium.pdf

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

Using the decay branching ratio database in Radiation Residue calculations

http://lise.nscl.msu.edu/9_10/Branching.pdf#page=7



Final Page

- Thanks to Prof. D.J.Morrisey and B.Sherrill for discussions

- The Decay Branch database should be updated
- Calculations should be optimized for the stiff problem