

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

Radiation residue calculator settings

Integration model

- ☒ ODE (ordinary differential equation solver) ISBN: 0716704617
- ☐ RKF45 (Runge-Kutta-Fehlberg ODE solver)
- ☐ Numerical Recipes: ODEINT
- ☐ Numerical Recipes: STIFF
- ☐ Numerical Recipes: STIFBS

Option	Value	Description	Default value
N_Implant	100	number of points : Irradiation	100
N_Decay	100	number of points : DECAY	100
AbsError	1.000e-11	absolute error tolerance	1e-11
RelError	1.000e-03	relative error tolerance	1e-03
Y_thrshld	1.000e-10	Minimum yield value	1e-10

At each step for first two models, the code requires
 $\text{abs}(\text{local error}) \leq \text{abs}(Y) * \text{RelErr} + \text{AbsErr}$

Isotopes to plot

- ☒ ALL (Stable & Radioactive)
- ☐ only Radioactive
- ☐ only Stable

2D-plot

- ☒ Z vs. N
- ☐ Z vs. N-Z
- ☐ Z vs. N-2Z

Half-life boundaries (sec)

T1/2_min = 1.0e-09 "unbound" below this value

T1/2_max = 1.0e+20 "stable" above this value

1e-19 < Tmin < Tmax < 1e+20

☒ "Isotope conservation law"
 (apply primary irradiation rates of
 eliminated nuclei to their daughters)

Number of none-dimensional distributions 20

☐ Make default

Try to keep the Decay time after irradiation larger than the $T_{1/2}$ min boundary

Radiation Residues as Function of time (DT) DT : Decay Time after irradiation (sec) = 100	>	Half-life boundaries (sec) T1/2_min = 1.0e-1 "unbound" below this value
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Radiation residue calculator

Mode to implant:

- ☒ 1. One nucleus to implant. Chose manually here
- ☐ 2. List of isotopes to implant from file
- ☐ 3. Select detector to obtain the list of isotopes stopped in

Designations:

Yield = Number of atoms; N of DI = Number of Different Isotopes; Final Time (FT) = Irradiation Time (IT) + Decay Time (DT)

1. Chose fragment to implant:

A	Element	Z
221	u	92
Unknown		

$T_{1/2} = 1.30\text{e-}06$ sec

Implantation Rate = $1\text{e+}10$ pps

Yield of this nucleus @ Irradiation time (IT) = 0

Yield of this nucleus @ Final time (FT) = 0

Irradiation (Implantation):

IT : Irradiation Time [sec] = 0.10

N of DI @ time (IT) = 16

Radiation Residues as Function of time (DT):

DT : Decay Time after irradiation (sec) = 0

N of DI @ time (FT) = 10

Total Yield @ time (FT) = $1\text{e+}9$

Buttons: Calculate, Options, View Results (Text), Quit, Link

Elapsed time is 00:00:01.73 or 1.73 sec

CAUTION RADIATION AREA

Radiation residue calculator settings

Integration model:

- ☒ ODE (ordinary differential equation solver) ISBN: 0716704617
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- ☐ Numerical Recipes: ODEINT
- ☐ Numerical Recipes: STIFF
- ☐ Numerical Recipes: STIFBS

Isotopes to plot:

- ☒ ALL (Stable & Radioactive)
- ☐ only Radioactive
- ☐ only Stable

Half-life boundaries (sec):

"unbound" below this value
 $T_{1/2_min} = 1.0\text{e-}08$

"stable" above this value
 $T_{1/2_max} = 1.0\text{e+}15$

$1\text{e-}19 < T_{min} < T_{max} < 1\text{e+}20$

Number of one-dimensional distributions: 100

Make default

Buttons: Ok, Cancel

At each step for first two models, the code requires
 $abs(\text{local error}) \leq abs(Y) * RelErr + AbsErr$

A_El	Z	N	Residue Atoms	T1/2, sec
201Pb	82	119	2.120e-10	3.359e+04
205Pb	82	123	1.029e-08	5.456e+14
205Bi	83	122	2.405e-02	1.323e+06
205Po	84	121	1.923e-01	6.264e+03
209Po	84	125	1.647e+03	3.217e+09
209At	85	124	4.945e+05	1.948e+04
209Rn	86	123	8.402e+04	1.710e+03
213Rn	86	127	1.138e+03	1.950e-02
213Fr	87	126	4.995e+08	3.482e+01
213Ra	88	125	4.981e+08	1.638e+02
217Ac	89	128	4.977e+02	6.900e-08
217Th	90	127	1.782e+06	2.470e-04
221Pa	91	130	4.255e+04	5.900e-06
221U	92	129	1.773e+04	1.300e-06

Half-life boundaries (sec)
 "unbound" below this value
 $T_{1/2_min} = 1.0\text{e-}08$

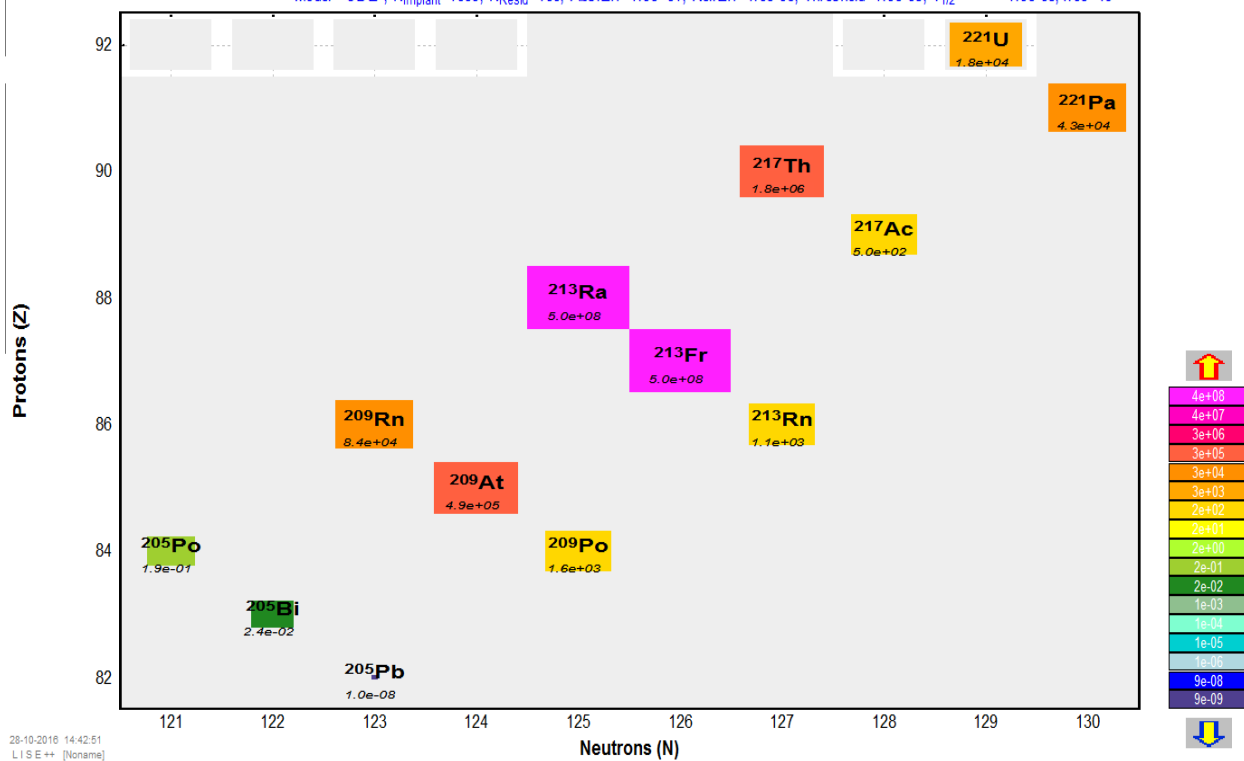
Irradiation (Implantation)
 IT : Irradiation Time [sec] = 0.1
 N of DI @ time (IT) = 16

Radiation Residues as Function of time (DT)
 DT : Decay Time after irradiation (sec) = 0
 N of DI @ time (FT) = 13
 Total Yield @ time (FT) = 1e+9

Radioactive decay residues

Initial isotope: ^{221}U

Irradiation Time (IT) = 1.00e-01 sec; Decay Time (DT) = 1.00e-07 sec; Irr.Rate = 1.00e+10 pps; Plot All isotopes
 Model="ODE", N_{Implan}=1000, N_{Resid}=100, Abs.Err=1.0e+01, Rel.Err=1.0e-03, Threshold=1.0e-08, $T_{1/2}^{\text{bounds}} = 1.0\text{e-}08, 1.0\text{e+}15$

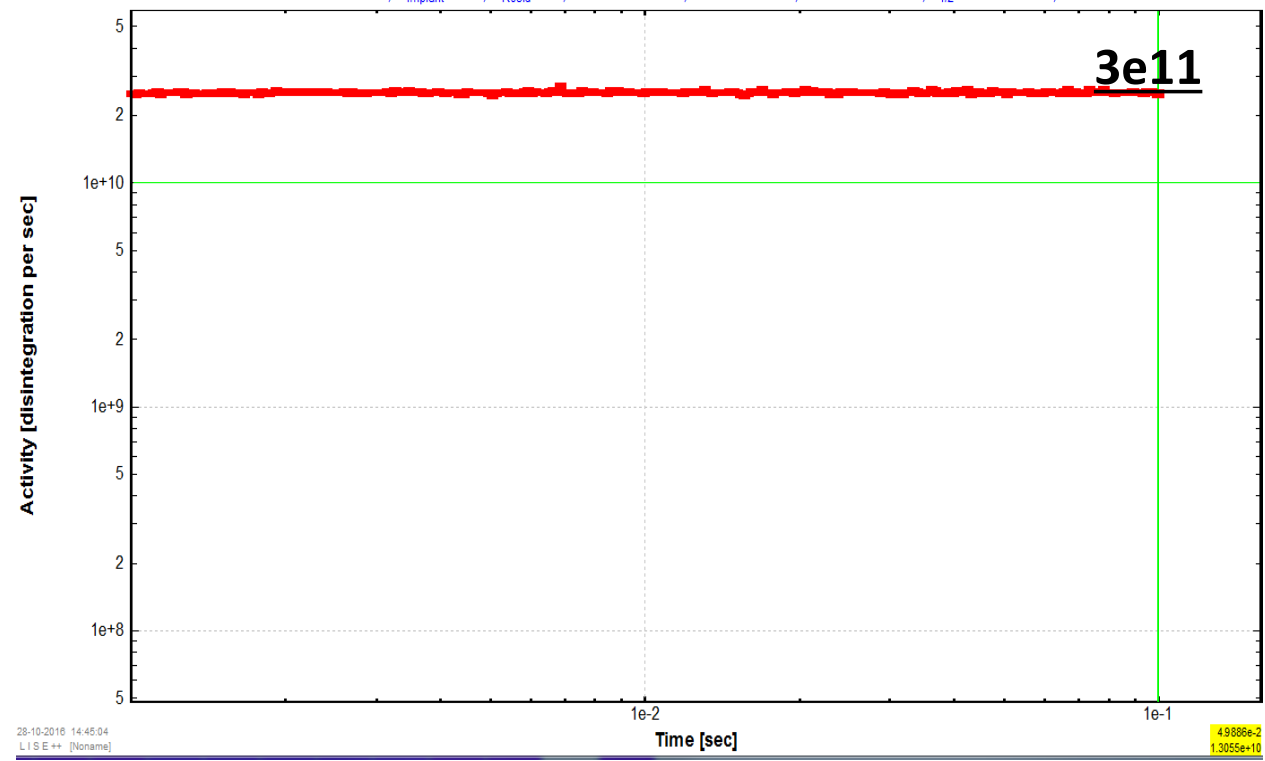


Activity

Initial isotope: ^{221}U

Irradiation Time (IT) = 1.00e-01 sec; Decay Time (DT) = 1.00e-07 sec; Irr.Rate = 1.00e+10 pps; Plot All isotopes
 Model="ODE", N_{Implan}=1000, N_{Resid}=100, Abs.Err=1.0e+01, Rel.Err=1.0e-03, Threshold=1.0e-08, $T_{1/2}^{\text{bounds}} = 1.0\text{e-}08, 1.0\text{e+}15$

Elapsed time is 00:00:06.07 or 6.07 sec



Half-life boundaries (sec)

"unbound" below this value

$T_{1/2_min} = 1.0\text{e-}05$

Irradiation (Implantation)

IT : Irradiation Time [sec] = 0.10

N of DI @ time (IT) = 16

Radiation Residues as Function of time (DT)

DT : Decay Time after irradiation (sec) = 0

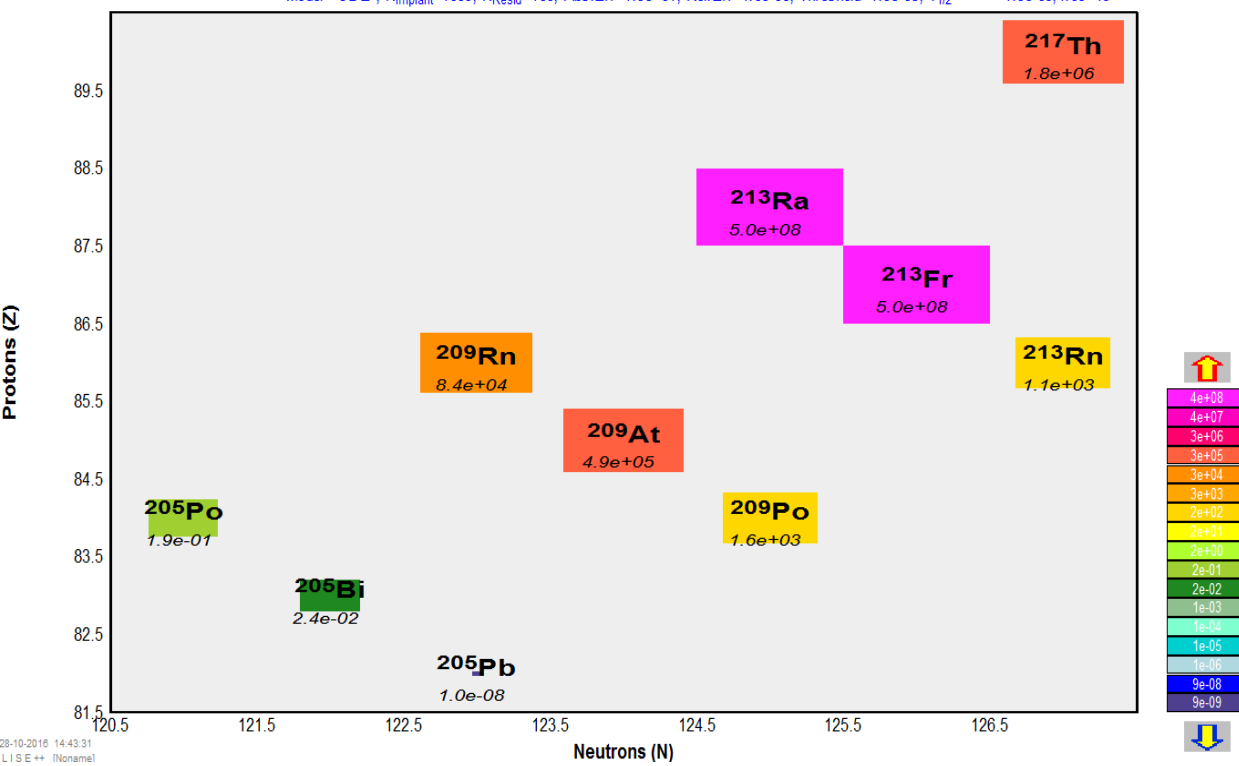
N of DI @ time (FT) = 10

Total Yield @ time (FT) = $1\text{e+}9$

Radioactive decay residues

Initial isotope: ^{221}U

Irradiation Time (IT) = $1.00\text{e-}01$ sec; Decay Time (DT) = $1.00\text{e-}07$ sec; Irr.Rate = $1.00\text{e+}10$ pps; Plot All isotopes
Model="ODE", $N_{\text{Implant}}=1000$, $N_{\text{Resid}}=100$, Abs.Err= $1.0\text{e+}01$, Rel.Err= $1.0\text{e-}03$, Threshold= $1.0\text{e-}08$, $T_{1/2_bounds}=1.0\text{e-}05, 1.0\text{e+}15$

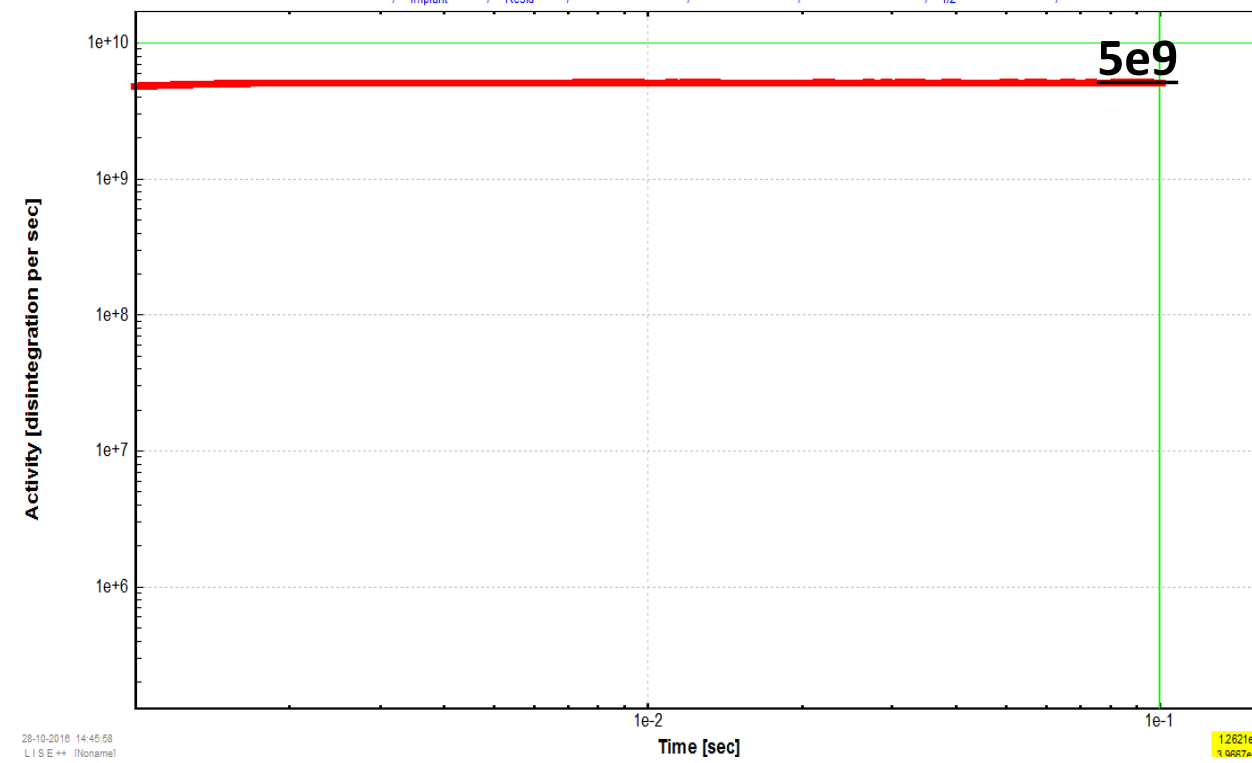


Activity

Initial isotope: ^{221}U

Irradiation Time (IT) = $1.00\text{e-}01$ sec; Decay Time (DT) = $1.00\text{e-}07$ sec; Irr.Rate = $1.00\text{e+}10$ pps; Plot All isotopes
Model="ODE", $N_{\text{Implant}}=1000$, $N_{\text{Resid}}=100$, Abs.Err= $1.0\text{e+}01$, Rel.Err= $1.0\text{e-}03$, Threshold= $1.0\text{e-}08$, $T_{1/2_bounds}=1.0\text{e-}05, 1.0\text{e+}15$

Elapsed time is 00:00:01.73 or 1.73 sec



Half-life boundaries (sec)

"unbound" below this value

$T_{1/2_min} = 1.0\text{e-}02$

Irradiation (Implantation)

IT : Irradiation Time [sec] = 0.1

N of DI @ time (IT) = 15

Radiation Residues as Function of time (DT)

DT : Decay Time after irradiation (sec) = 0.

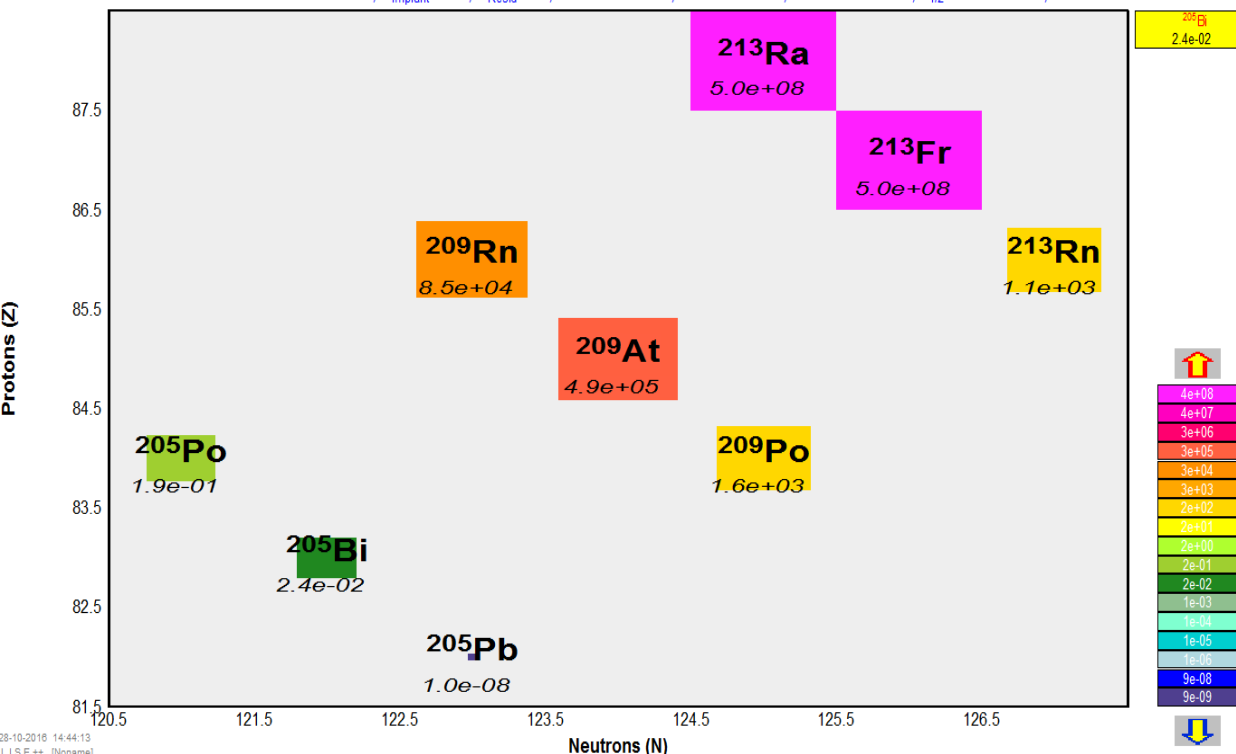
N of DI @ time (FT) = 9

Total Yield @ time (FT) = $1\text{e+}9$

Radioactive decay residues

Initial isotope: ^{221}U

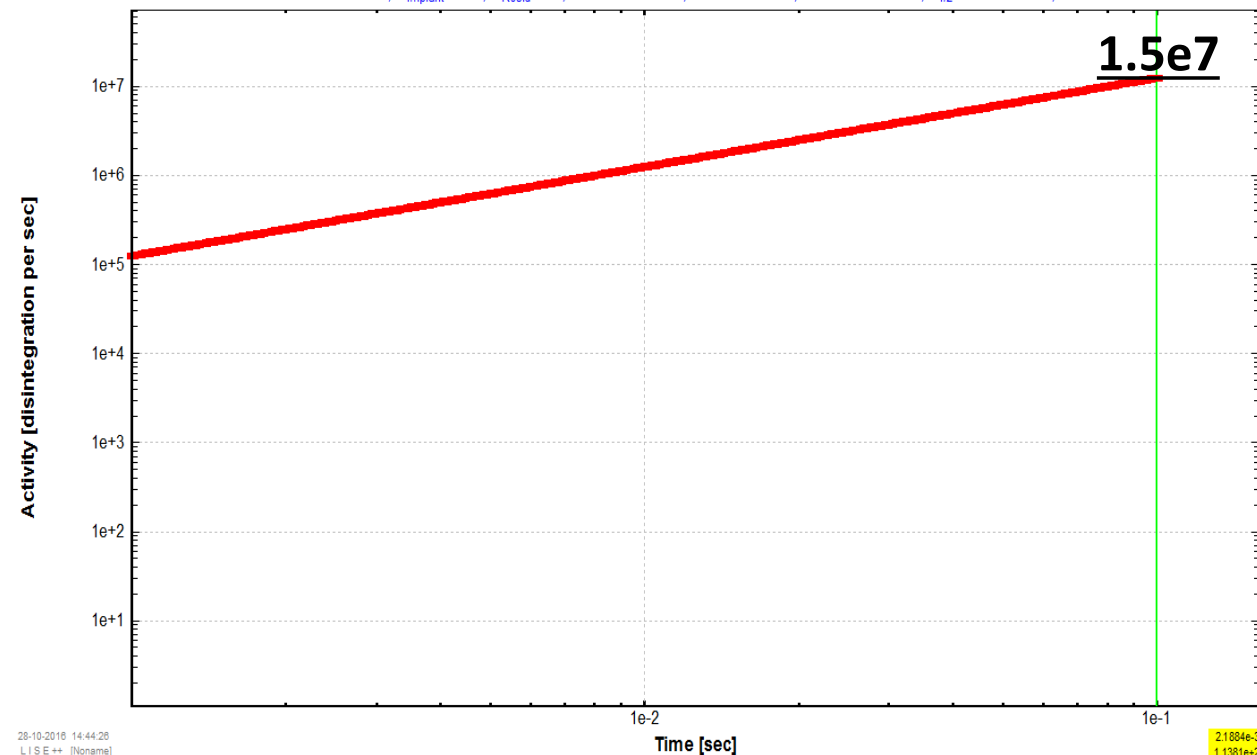
Irradiation Time (IT) = $1.00\text{e-}01\text{ sec}$; Decay Time (DT) = $1.00\text{e-}07\text{ sec}$; Irr.Rate = $1.00\text{e+}10\text{ pps}$; Plot All isotopes
Model="ODE", $N_{\text{Implant}}=1000$, $N_{\text{Resid}}=100$, Abs.Err= $1.0\text{e+}01$, Rel.Err= $1.0\text{e-}03$, Threshold= $1.0\text{e-}08$, $T_{1/2}^{\text{bounds}}=1.0\text{e-}02, 1.0\text{e+}15$



Activity

Initial isotope: ^{221}U

Irradiation Time (IT) = $1.00\text{e-}01\text{ sec}$; Decay Time (DT) = $1.00\text{e-}07\text{ sec}$; Irr.Rate = $1.00\text{e+}10\text{ pps}$; Plot All isotopes
Model="ODE", $N_{\text{Implant}}=1000$, $N_{\text{Resid}}=100$, Abs.Err= $1.0\text{e+}01$, Rel.Err= $1.0\text{e-}03$, Threshold= $1.0\text{e-}08$, $T_{1/2}^{\text{bounds}}=1.0\text{e-}02, 1.0\text{e+}15$



Elapsed time is 00:00:00.57 or 0.57 sec

^{221}U irradiation case : Decay time = 100 s, $T_{\min} = 1\text{e-}2$ & $1\text{e-}8$ s

Half-life boundaries (sec)

"unbound" below this value

$T_{1/2_min} = 1.0\text{e-}02$

Irradiation (Implantation)

IT : Irradiation Time [sec] = 0.1

N of DI @ time (IT) = 15

Radiation Residues as Function of time (DT)

DT : Decay Time after irradiation (sec) = 100

N of DI @ time (FT) = 11

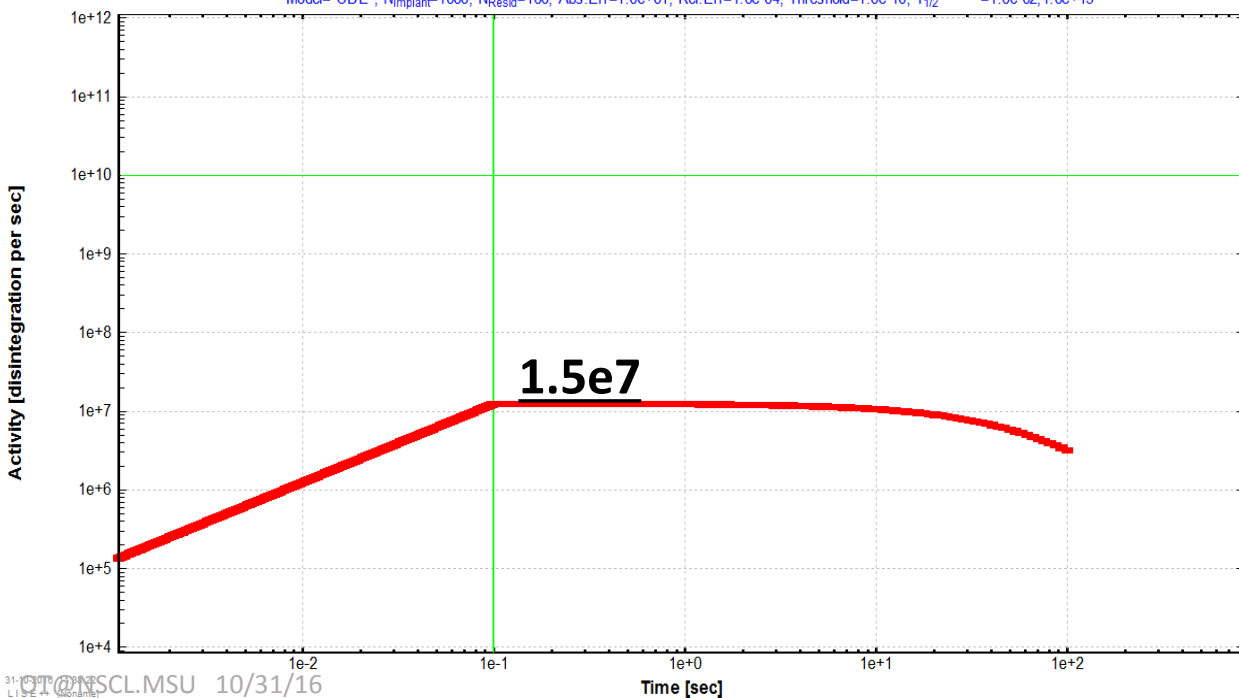
Total Yield @ time (FT) = $1\text{e+}9$

Elapsed time is 00:00:00.81
or 0.81 sec

Activity

Initial isotope: ^{221}U

Irradiation Time (IT) = $1.00\text{e-}01$ sec; Decay Time (DT) = $1.00\text{e+}02$ sec; Irr.Rate = $1.00\text{e+}10$ pps; Plot All isotopes
Model="ODE", $N_{\text{implant}}=1000$, $N_{\text{Resid}}=100$, Abs.Err= $1.0\text{e+}01$, Rel.Err= $1.0\text{e-}04$, Threshold= $1.0\text{e-}10$, $T_{1/2}^{\text{bounds}}=1.0\text{e-}02, 1.0\text{e+}15$



Irradiation (Implantation)

IT : Irradiation Time [sec] = 0.10

N of DI @ time (IT) = 15

Radiation Residues as Function of time (DT)

DT : Decay Time after irradiation (sec) = 100.

N of DI @ time (FT) = 11

Total Yield @ time (FT) = $1\text{e+}9$

Elapsed time is 00:00:09.09
or 9.09 sec

Half-life boundaries (sec)

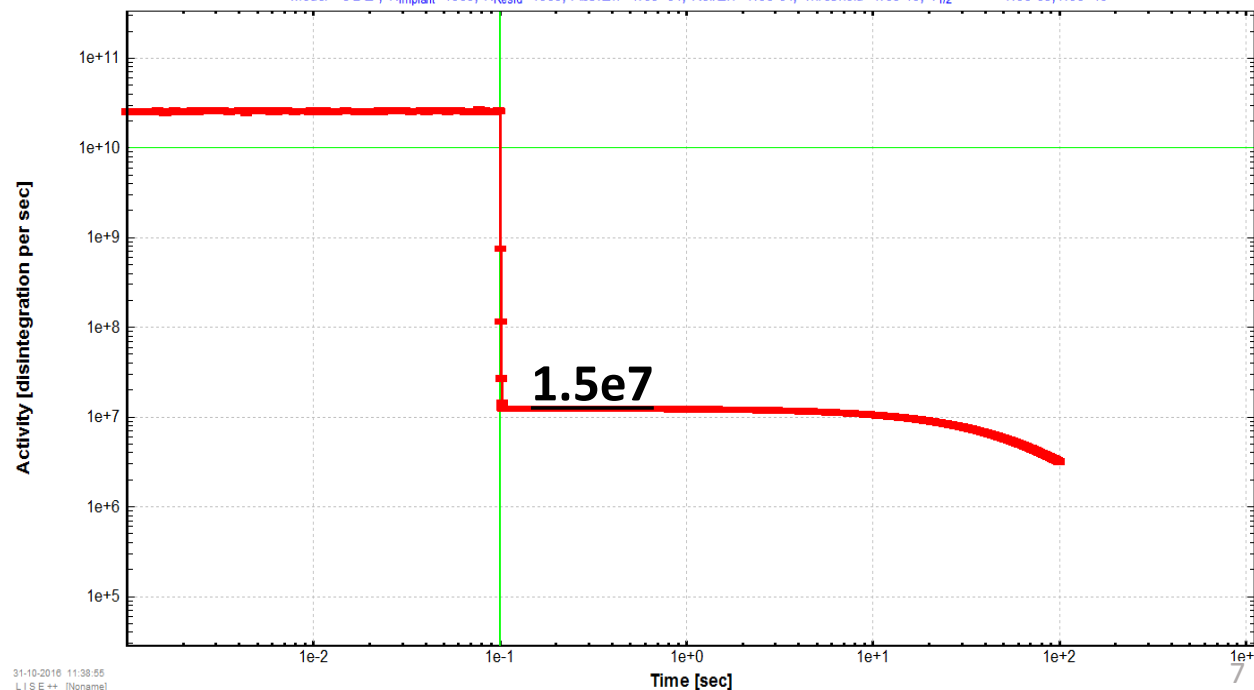
"unbound" below this value

$T_{1/2_min} = 1.0\text{e-}08$

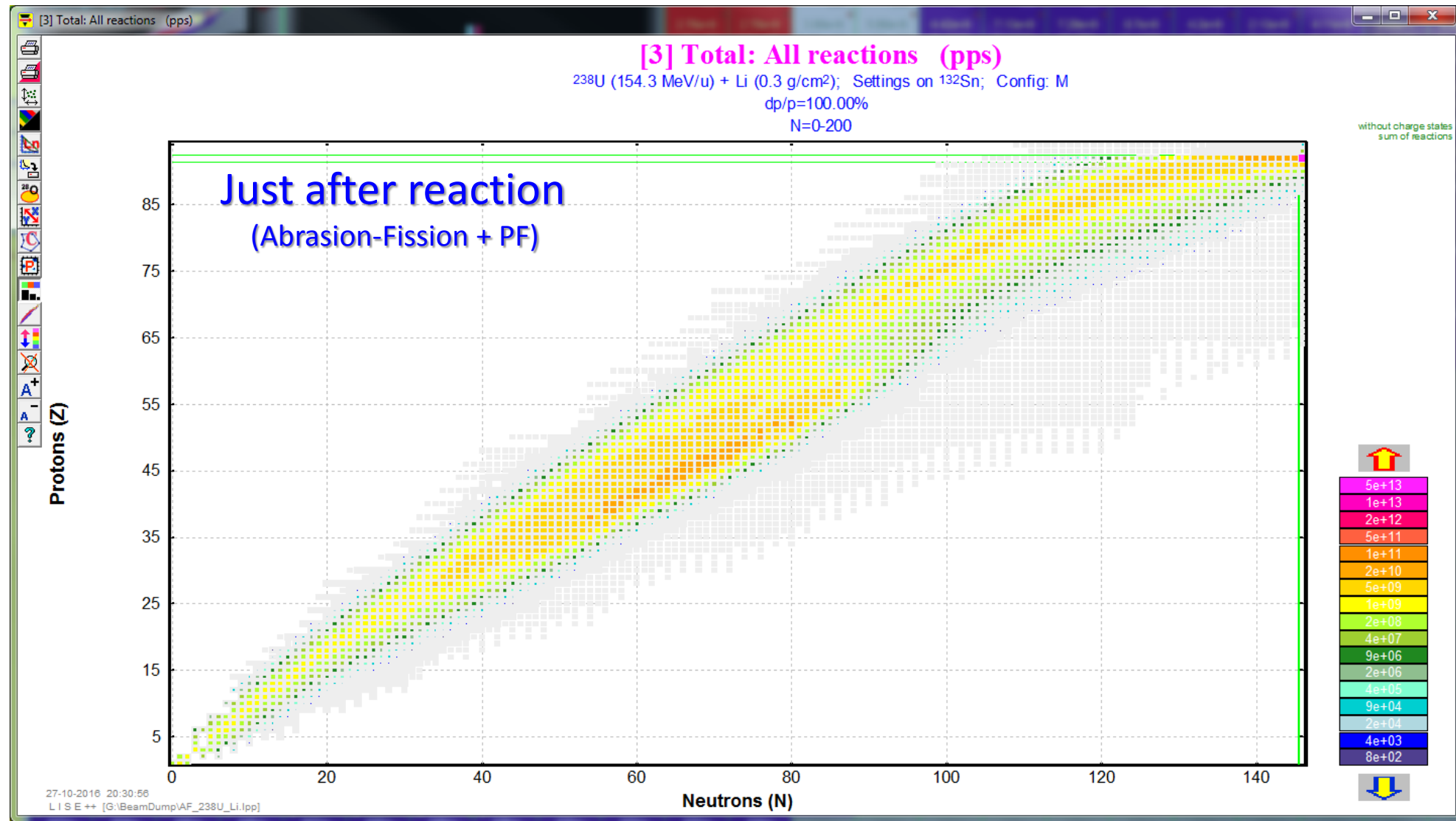
Activity

Initial isotope: ^{221}U

Irradiation Time (IT) = $1.00\text{e-}01$ sec; Decay Time (DT) = $1.00\text{e+}02$ sec; Irr.Rate = $1.00\text{e+}10$ pps; Plot All isotopes
Model="ODE", $N_{\text{implant}}=1000$, $N_{\text{Resid}}=1000$, Abs.Err= $1.0\text{e+}01$, Rel.Err= $1.0\text{e-}04$, Threshold= $1.0\text{e-}10$, $T_{1/2}^{\text{bounds}}=1.0\text{e-}08, 1.0\text{e+}15$



		@ 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



Radiation residue calculator

Mode to implant

- ☐ 1. One nucleus to implant. Chose manually here
- ☒ 2. List of isotopes to implant from file
- ☐ 3. Select detector to obtain the list of isotopes stopped in

Designations

Yield = Number of atoms; N of DI = Number of Different Isotopes; Final Time (FT) = Irradiation Time (IT) + Decay Time (DT)

File: "238U_all2.radlist" N of isotopes = 2647

Detector: FP_PPAC0 Refresh N of isotopes = 0

Press "Escape" to interrupt calculations

Total Irradiation Rate

Rate = 7.061e+13 pps

CAUTION RADIATION AREA

Calculate Options

1D : Residues as function of time

1D : Activity as function of time

2D : Final Residues (@ TF)

View Results (Text)

Quit Link

Elapsed time is 00:02:30.96 or 150.96 sec

Irradiation (Implantation)

IT : Irradiation Time [sec] = 0.0001

N of DI @ time (IT) = 2598

Radiation Residues as Function of time (DT)

DT : Decay Time after irradiation (sec) = 0

N of DI @ time (FT) = 2581

Total Yield @ time (FT) = 7.06e+9

Radiation residue calculator settings

Integration model

- ☒ ODE (ordinary differential equation solver) ISBN: 0716704617
- ☐ RKF45 (Runge-Kutta-Fehlberg ODE solver)
- ☐ Numerical Recipes: ODEINT
- ☐ Numerical Recipes: STIFF
- ☐ Numerical Recipes: STIFBS

Isotopes to plot

- ☒ ALL (Stable & Radioactive)
- ☐ only Radioactive
- ☐ only Stable

Half-life boundaries (sec)

"unbound" below this value

$T_{1/2_min} = 1.0e-10$

"stable" above this value

$T_{1/2_max} = 1.0e+10$

$1e-19 < T_{1/2_min} < T_{1/2_max} < 1e+20$

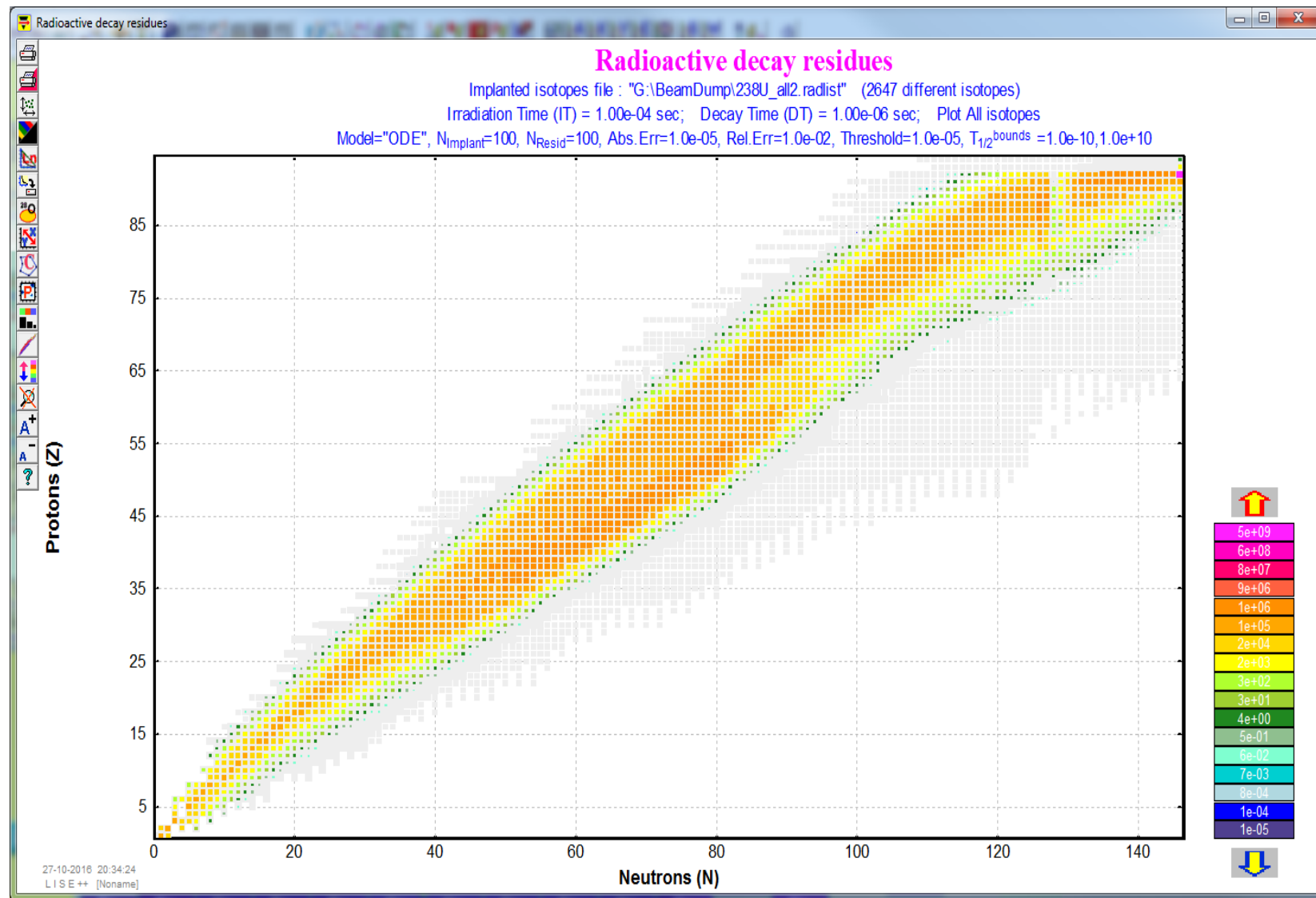
Number of one-dimensional distributions: 100

Make default

Ok Cancel

At each step for first two models, the code requires $abs(local\ error) \leq abs(Y) * RelErr + AbsErr$

Option	Value	Description	Default value
N_Implant	100	number of points : Irradiation	100
N_Decay	100	number of points : DECAy	100
AbsError	1.000e-05	absolute error tolerance	1e-11
RelError	1.000e-02	relative error tolerance	1e-03
Y_thrsld	1.000e-05	Minimum yield value	1e-10



No stiffness!

Radiation residue calculator

Mode to implant:

- ☐ 1. One nucleus to implant. Chose manually here
- ☒ 2. List of isotopes to implant from file
- ☐ 3. Select detector to obtain the list of isotopes stopped in

designations:
Yield = Number of atoms; N of DI = Number of Different Isotopes;
Final Time (FT) = Irradiation Time (IT) + Decay Time (DT)

File: "238U_all2.radlist" N of isotopes = 2647

FP_PPAC0 Refresh N of isotopes = 0

Press "Escape" to interrupt calculations

Total Irradiation Rate
Rate = 7.035e+13 pps

CAUTION RADIATION AREA

Calculate Options

1D : Residues as function of time
1D : Activity as function of time
2D : Final Residues (@ TF)

Irradiation (Implantation)

IT : Irradiation Time [sec] = 1000
N of DI @ time (IT) = 2304

Radiation Residues as Function of time (DT)

DT : Decay Time after irradiation (sec) = 0
N of DI @ time (FT) = 2289
Total Yield @ time (FT) = 7.02e+16

View Results (Text)

Elapsed time is 00:00:04.46 or 4.46 sec

Radiation residue calculator settings

Integration model

- ☒ ODE (ordinary differential equation solver) ISBN: 0716704617
- ☐ RK45 (Runge-Kutta-Fehlberg ODE solver)
- ☐ Numerical Recipes: ODEINT
- ☐ Numerical Recipes: STIFF
- ☐ Numerical Recipes: STIFBS

Option	Value	Description	Default value
N_Implant	100	number of points : Irradiation	100
N_Decay	100	number of points : DECAy	100
AbsError	1.000e+01	absolute error tolerance	1e-11
RelError	1.000e-02	relative error tolerance	1e-03
Y_thrsld	1.000e+02	Minimum yield value	1e-10

At each step for first two models, the code requires
abs local error $\leq \text{abs}(Y) * \text{RelErr} + \text{AbsErr}$

Isotopes to plot

- ☒ ALL (Stable & Radioactive)
- ☐ only Radioactive
- ☐ only Stable

Half-life boundaries (sec)

"unbound" below this value
T1/2_min = 1.0e-02

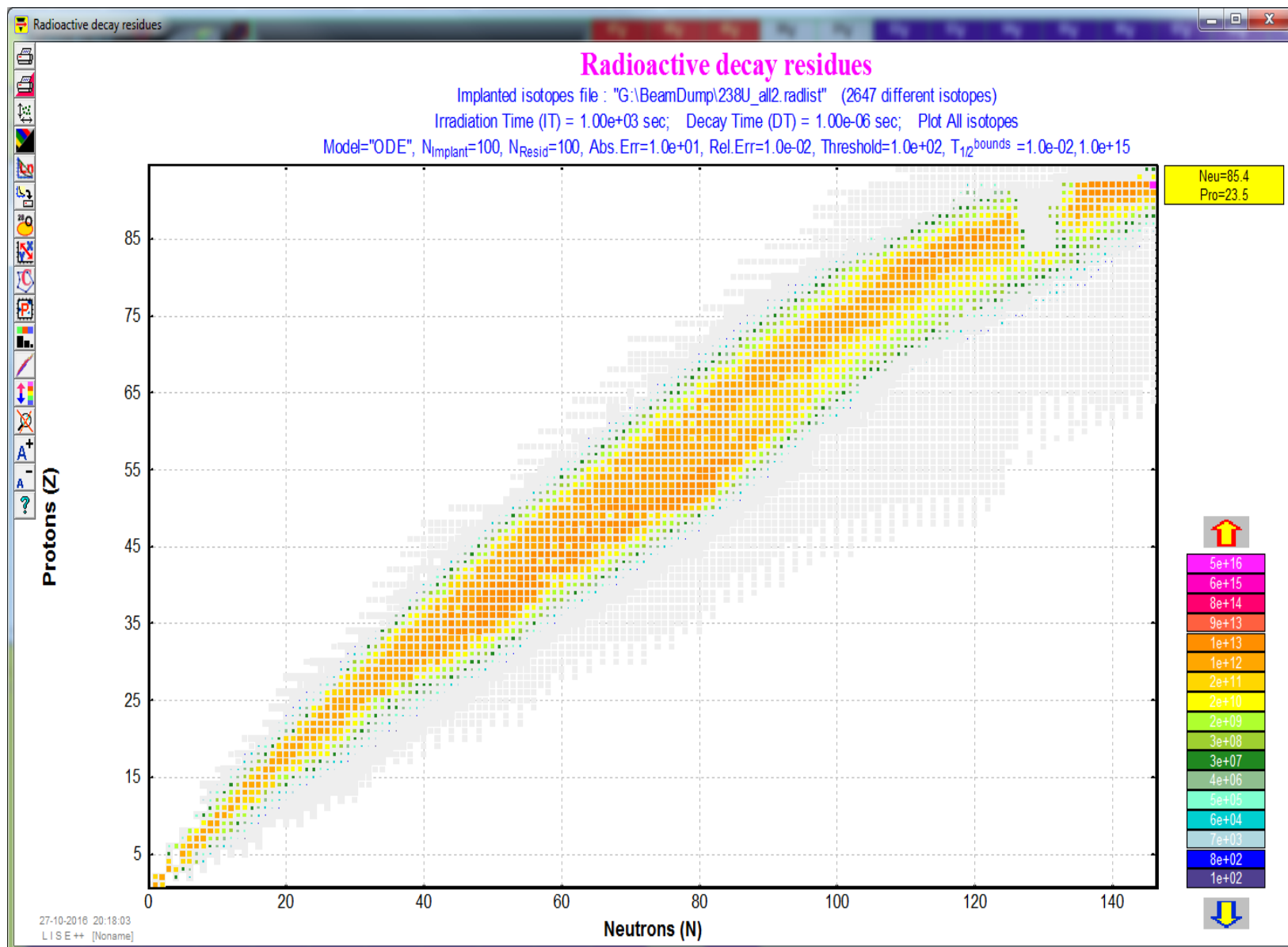
"stable" above this value
T1/2_max = 1.0e+15

1e-19 < T1/2_min < T1/2_max < 1e+20

Number of one-dimensional distributions: 100

Make default

Ok Cancel



No stiffness!

Radiation residue calculator

Mode to implant:

- ☐ 1. One nucleus to implant. Chose manually here
- ☒ 2. List of isotopes to implant from file
- ☐ 3. Select detector to obtain the list of isotopes stopped in

designations:

Yield = Number of atoms; N of DI = Number of Different Isotopes;
Final Time (FT) = Irradiation Time (IT) + Decay Time (DT)

"238U_all2.radiist" N of isotopes = 2647

FP_PPAC0 Refresh N of isotopes = 0

Press "Escape" to interrupt calculations

Total Irradiation Rate

Rate = 7.035e+13 pps

CAUTION RADIATION AREA

Calculate Options

1D: Residues as function of time

1D: Activity as function of time

2D: Final Residues (@ TF)

Irradiation (Implantation)

IT: Irradiation Time (sec) = 1000

N of DI @ time (IT) = 2304

Radiation Residues as Function of time (DT)

DT: Decay Time after irradiation (sec) = 10000

N of DI @ time (FT) = 1111

Total Yield @ time (FT) = 7.02e+16

View Results (Text)

Elapsed time is 00:00:40.77 or 40.77 sec

Radiation residue calculator settings

Integration model

- ☒ ODE (ordinary differential equation solver) ISBN: 0716704617
- ☐ RK45 (Runge-Kutta-Fehlberg ODE solver)
- ☐ Numerical Recipes: ODEINT
- ☐ Numerical Recipes: STIFF
- ☐ Numerical Recipes: STIFBS

Isotopes to plot

- ☒ ALL (Stable & Radioactive)
- ☐ only Radioactive
- ☐ only Stable

Half-life boundaries (sec)

"unbound" below this value

T1/2_min = 1.0e-01

"stable" above this value

T1/2_max = 1.0e+15

1e-19 < T1/2_min < T1/2_max < 1e+20

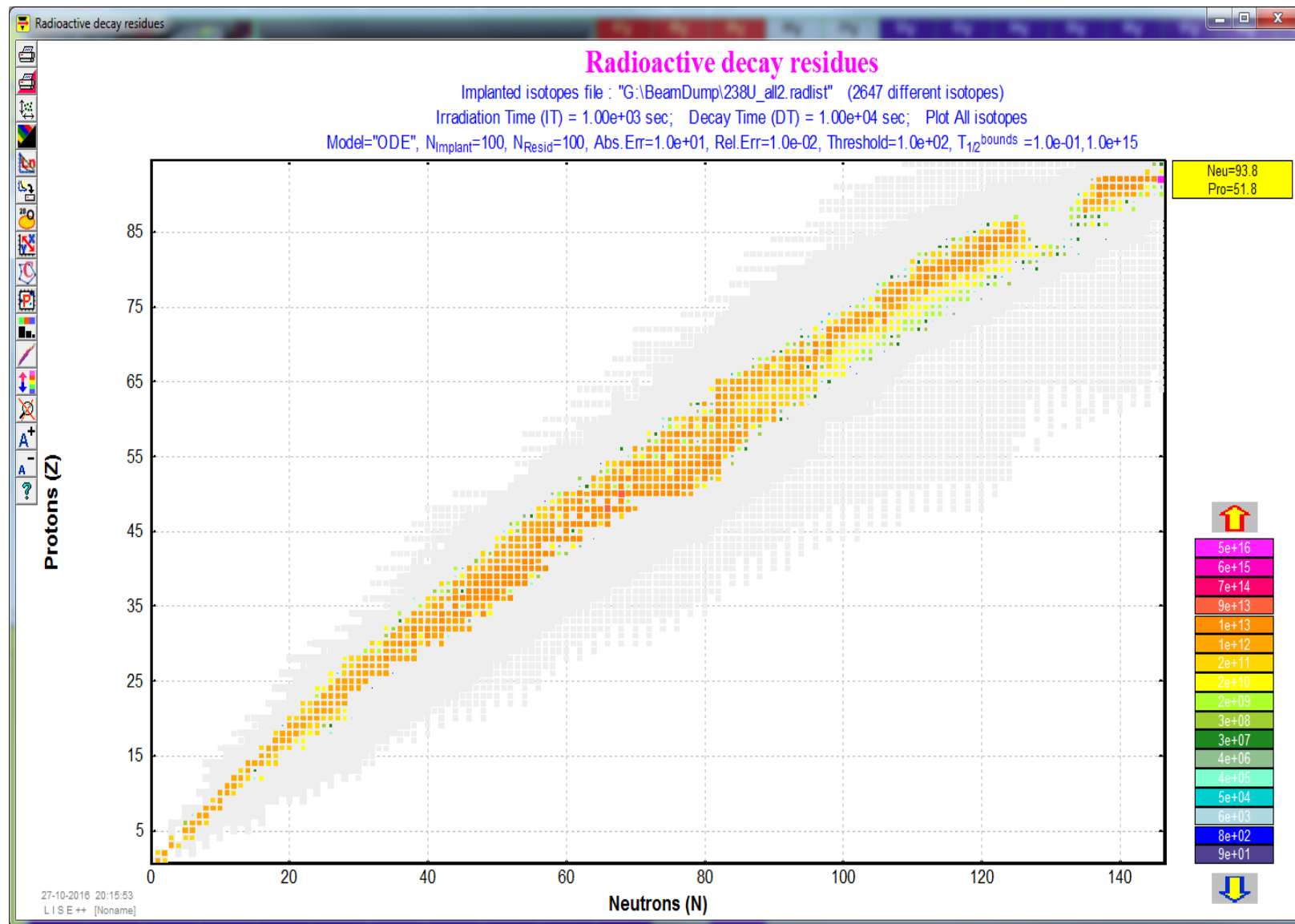
Number of one-dimensional distributions = 100

Make default

Ok Cancel

Option	Value	Description	Default value
N_Implant	100	number of points: Irradiation	100
N_Decay	100	number of points: DECAY	100
AbsError	1.000e+01	absolute error tolerance	1e-11
RelError	1.000e-02	relative error tolerance	1e-03
Y_thshld	1.000e+02	Minimum yield value	1e-10

At each step for first two models, the code requires
absl local error $\leq \text{abs}(Y) * \text{RelErr} + \text{AbsErr}$



No stiffness!