Version 8.3.6. Stripper lifetime

Stripper Lifetime

(version 8.3.6)

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  - Shape
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  - Material properties
  - Sublimation [1]
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  - Radiation damages
- Pulsing beam
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- Comparison with experimental data
  - ^{40}Ar @ Dubna : Radiation damages
  - ^{20}Ne @ Dubna : Radiation damages
  - ^{112}Sn @ MSU : Radiation damages
  - ^{238}U @ MSU : ?
  - H^- @ BNL [1] *: sublimation*

Versions 8.3.1 – 8.3.4

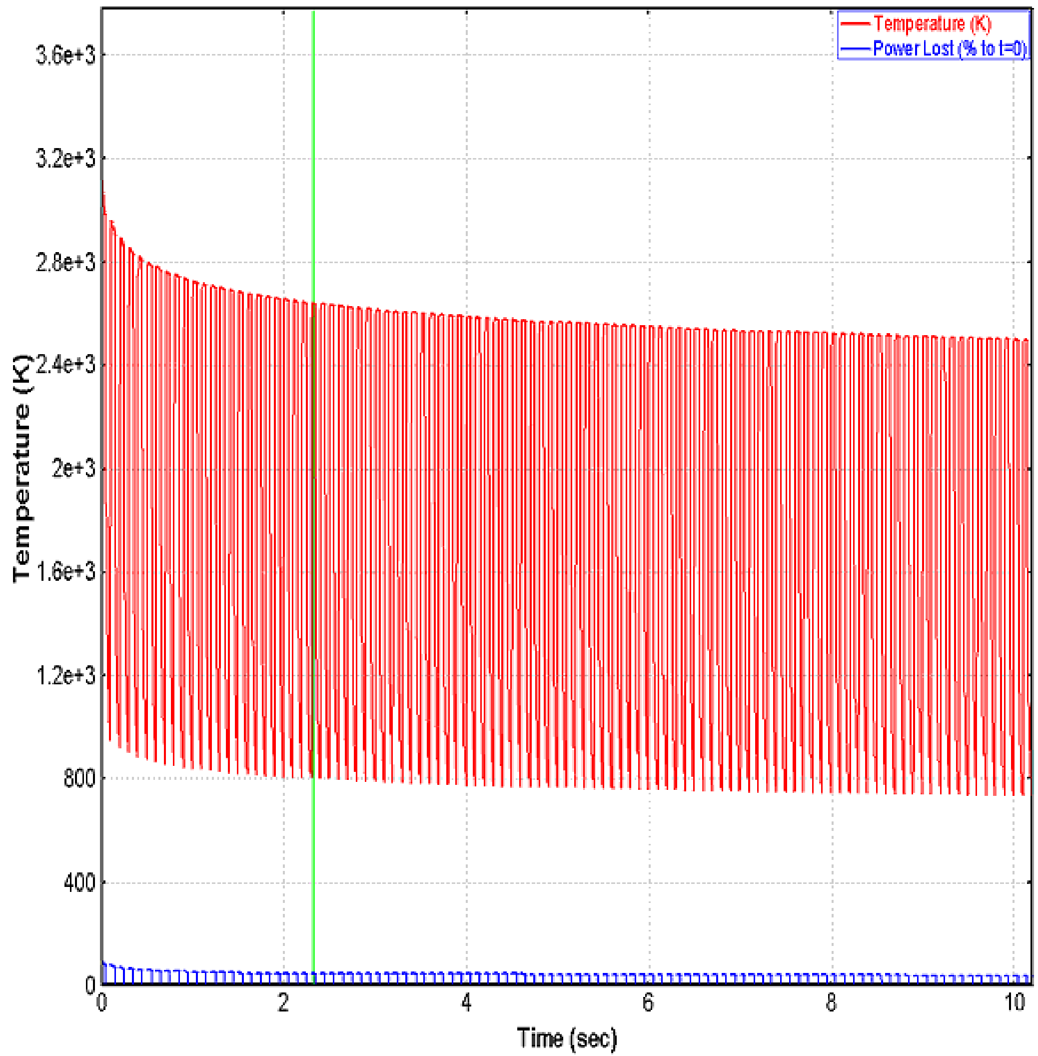
- Plot dialog: button "NZ chart"
- MC dialog : Rays generator
- 2D plot Contour : new value <XY>

Influence of submlimation (Pulsing beam [1]): Temperature

^{238}U Projectile Energy: 7.68 MeV/u Foil: C (0.4 mg/cm^2)

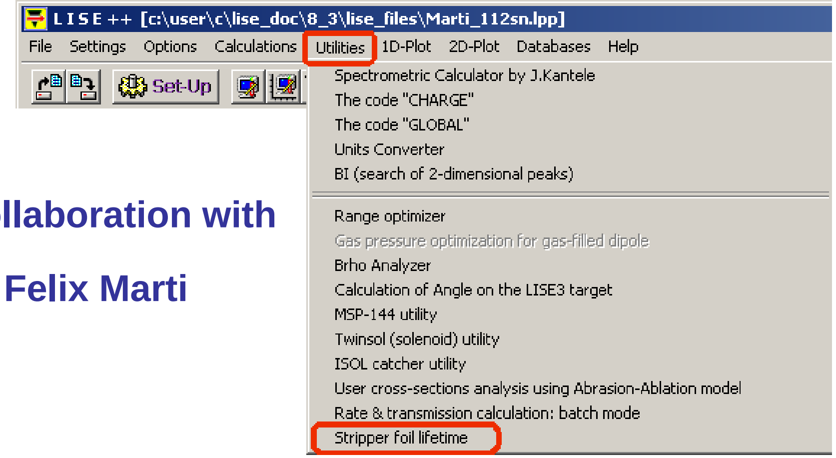
Left plot : Pulsing beam On-off Ratio = 50.00% Pulse length = 0.05 sec; Repetition rate = 10 sec^{-1}

Beam current = 1.6e+04 W/cm^2 or 8.5 puA/cm^2; epsilon=0.40; Lifetime = 2.32 sec



The code operates under MS Windows environment and provides a highly user-friendly interface.
It can be freely downloaded from the following internet addresses:
http://www.nscl.msu/edu/lise

Stripper lifetime utility in LISE++

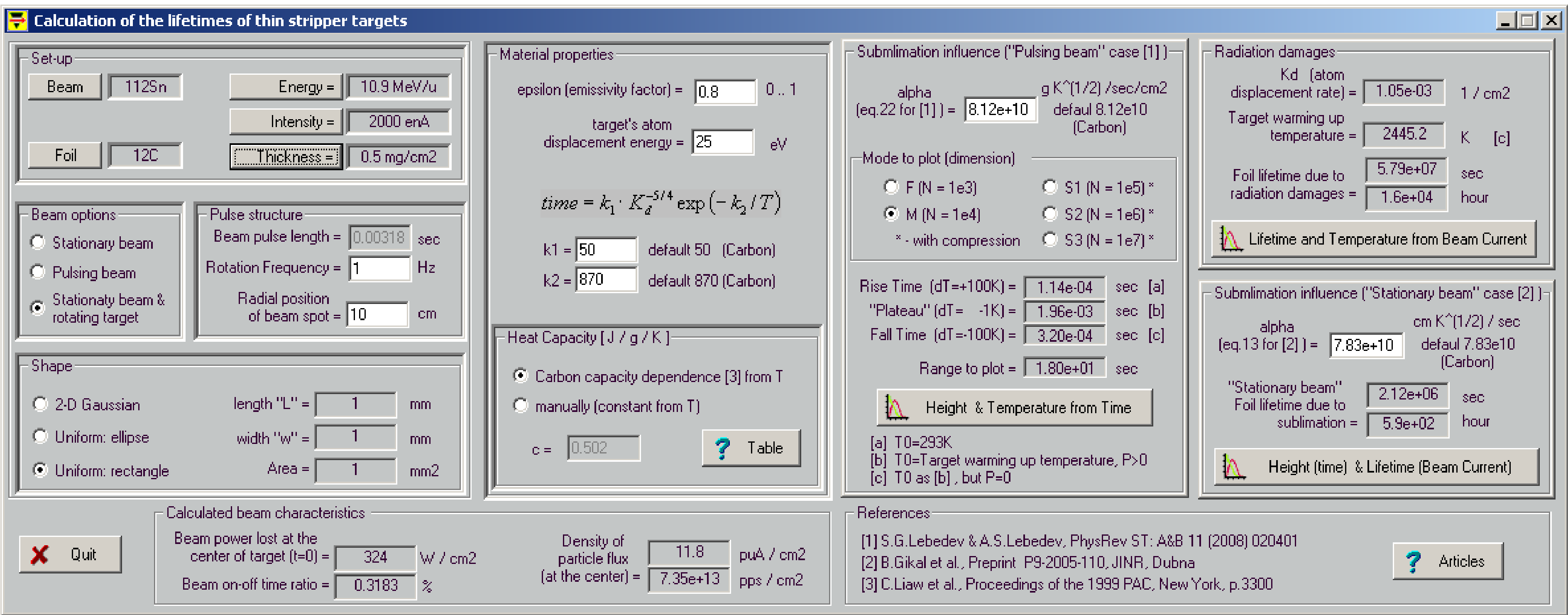


In collaboration with

Felix Marti

Why in LISE++ ?

- Recent experiments with heavy beams (U,Pb) show necessity of such calculations
- Easy data entry (Beam, Target dialogs)
- Energy loss models implemented in the code can be used to estimate beam power lost in targets
- In-built mathematical apparatus (integration and so on)
- Graphic library developed in the LISE++ package to plot obtained results



Principal papers

References

[1] S.G.Lebedev & A.S.Lebedev, PhysRev ST: A&B 11 (2008) 020401

[2] B.Gikal et al., Preprint P9-2005-110, JINR, Dubna

[3] C.Liaw et al., Proceedings of the 1999 PAC, New York, p.3300

Articles

http://groups.nscl.msu.edu/lise/paper/foil/

Index of /lise/paper/foil

Name	Last modified	Size	Description
Parent Directory		-	
Gikal_JINR_P9-2005-110_english.pdf	29-Mar-2008 13:01	239K	
Lebedev_PRAB11_2008_strippers_lifetime.pdf	04-Mar-2008 13:13	256K	
Liaw_PAC99_Carbon Foil Temperature.pdf	10-Apr-2008 11:40	39K	

Translated by O.B.Tarasov
tarasov@nscl.msu.edu
03/30/08

Calculation of Lifetime of Charge-Exchanging Carbon Targets in Intense Heavy Ion Beams

B.N.Gikal, G.G.Gulbekjan, V.I.Kazacha, D.V.Kamanin

P9-2005-110

Abstract: *Influence of the radiation damage and sublimation effects on the lifetime of carbon targets used for the accelerated ion beam extraction from cyclotrons by the charge-exchanging method is considered. The theoretical models permitting evaluation of the carbon target lifetime depending on their and ion beam parameters are presented both for the radiation damage and sublimation effects. It is shown that for the U-400 cyclotron carbon targets 50 ug/cm² thick and for the ion beam flux density up to 100 puA/cm² the main effect defining the carbon target lifetime is the radiation damage. If the carbon target thickness and the ion beam flux density are greater, the target lifetime is defined already by the sublimation effect. In this connection "casting pipes" can be formed in the target, affecting on the mean energy and the energy distribution dispersion of the ion beam lied through the target. Comparison of measured and calculated target lifetimes is carried out.*

The investigation has been performed at the Flerov Laboratory of Nuclear Reactions, JINR.

Communications of the Joint Institute for Nuclear Research. Dubna, 2005

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **11**, 020401 (2008)

Calculation of the lifetimes of thin stripper targets under bombardment of intense pulsed ions

S. G. Lebedev[1] and A. S. Lebedev[2]

[1]*Institute for Nuclear Research of the Russian Academy of Sciences, 60th October Anniversary Prospect, 7a, Moscow, 117312, Russia*
[2]*Lomonosov Moscow State University, Faculty of Calculus Mathematics and Cybernetics, Vorobievy Gory, GSP-2, Moscow, 119992, Russia*

(Received 10 June 2007; published 11 February 2008)

The problems of stripper target behavior in the nonstationary intense particle beams are considered. The historical sketch on studies of radiation damage failure of carbon targets under ion bombardment is presented. The simple model of target evaporation under intensive pulsing beam is supposed. Lifetimes of stripper targets under intensive nonstationary beams can be described by two failure mechanisms: radiation damage accumulation and evaporation of a target. At the maximal temperatures less than 2500°K the radiation damage dominates; at temperatures above 2500°K the mechanism of evaporation of a foil prevails. The proposed approach has been applied to the description of stripper foils behavior in Brookhaven National Laboratory linac and Spallation Neutron Source conditions.

DOI: 10.1103/PhysRevSTAB.11.020401 PACS numbers: 29.27.−a, 81.40.Np, 85.70.Kh

Proceedings of the 1999 Particle Accelerator Conference, New York, 1999

CALCULATION OF THE MAXIMUM TEMPERATURE ON THE CARBON STRIPPING FOIL OF THE SPALLATION NEUTRON SOURCE

C.J. Liaw, Y.Y. Lee, J. Alessi, J. Tuozzolo, BNL, Upton, NY 11973

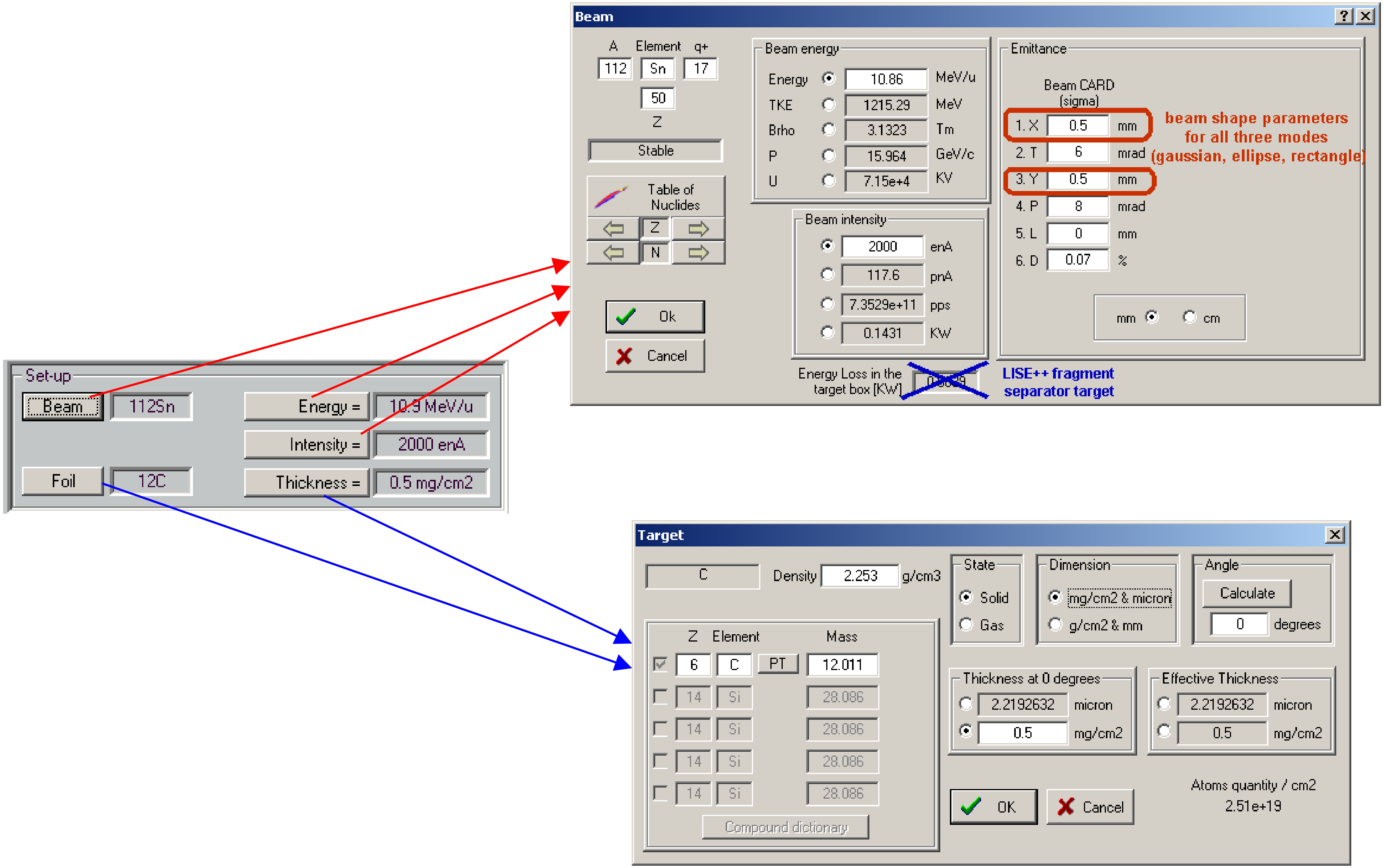
Abstract

The maximum temperatures expected on both 220 μg/cm² and 400 μg/cm² carbon foils, used to strip the 1 GeV H⁻ beam at injection into the accumulator ring of the Spallation Neutron Source (SNS), were determined by finite-element analysis. This beam will have a pulse length of 1 ms with a repetition rate of 60 Hz and an average current over a single beam pulse of 18.2 mA. The foil size will be 10 mm x 30 mm and will be mounted in a 20 cm diameter stainless steel beam pipe in the injection μg/cm² foils. A 225 μg/cm² thick carbon foil was tested to verify the analysis result. More testing to determine foil lifetime is planned.

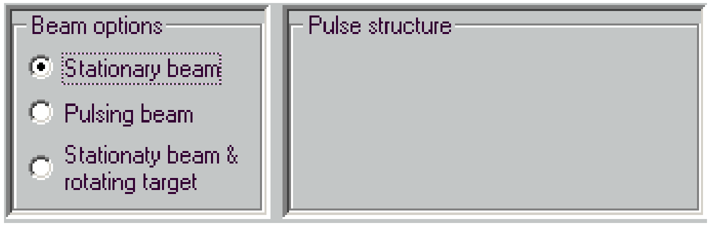
2 THERMAL ANALYSIS OF THE CARBON STRIPPING FOIL

The carbon foil (10 mm x 30 mm) will be mounted in a 20 cm diameter stainless steel beam pipe in the injection area of SNS. Fig. 1 shows the layout of SNS injection foil and the model that was used for the thermal analysis.

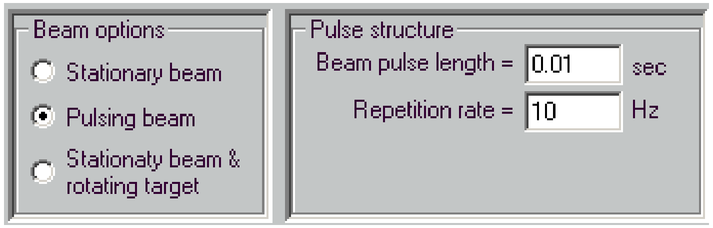
Dialog : Beam settings

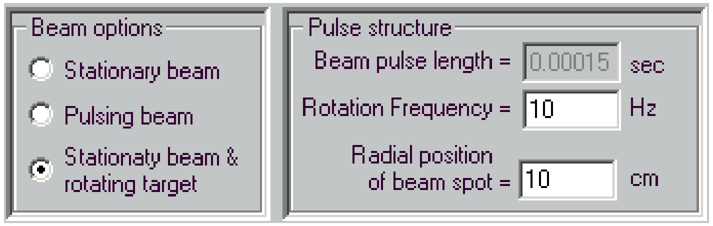


Dialog : Beam options (stationary / pulsing)



Rectangle shape of pulse



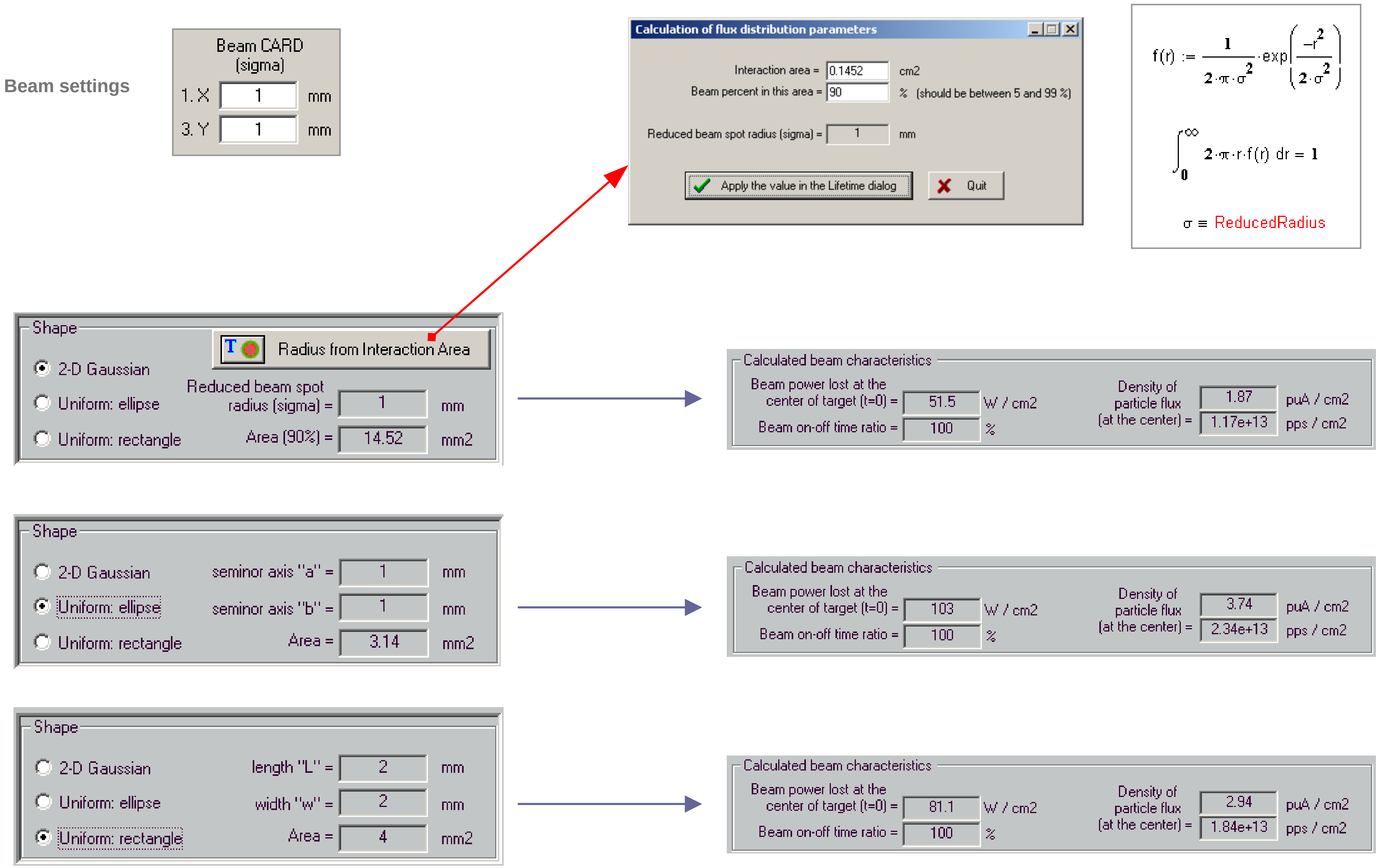


$$\tau = \frac{R_{reduced}}{\pi \, \nu \, R_{pos}}$$

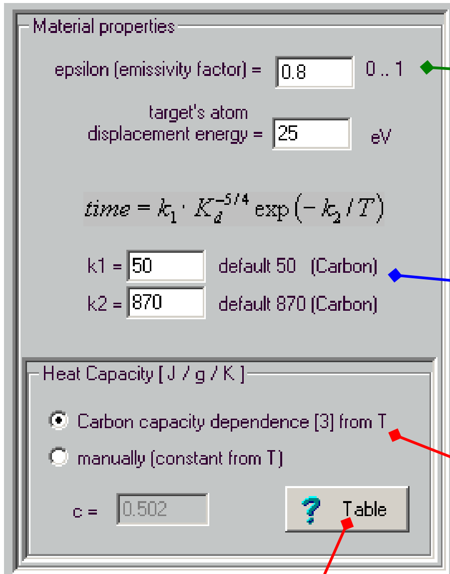
$$\text{Reduced Radius} = \sqrt{\text{beam.x} \cdot \text{beam.y}}$$

Beam on-off time ratio is applied for Radiation damages normalization

Dialog : Shape settings



Dialog : Material properties



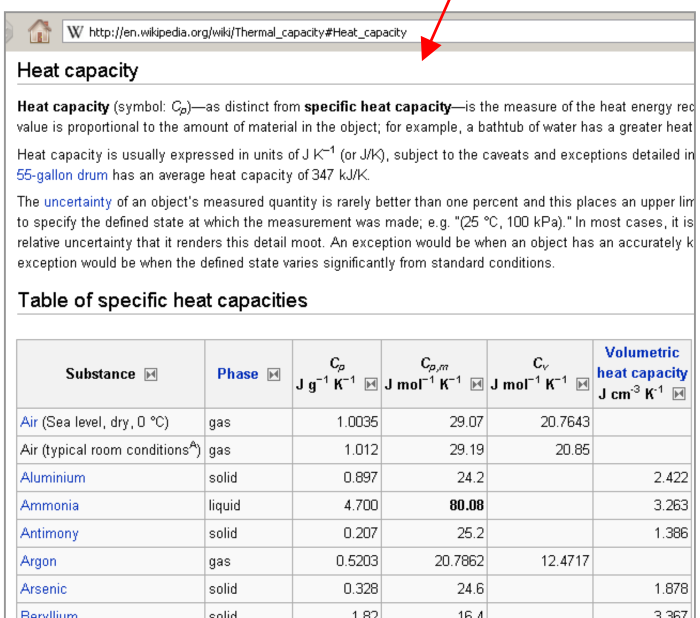
Carbon: [2] 0.5, 0.8; [3] 0.8

[1] $t = 50 K_d^{-(5/4)} \exp\left(-\frac{870}{T}\right)$

[2] $\tau_i = 23 \cdot K_d^{5/4} \cdot \exp(-870/T)$

K_d – atom displacement rate

It is used only in "Sublimation influence" [1]



http://en.wikipedia.org/wiki/Thermal_capacity#Heat_capacity

Heat capacity

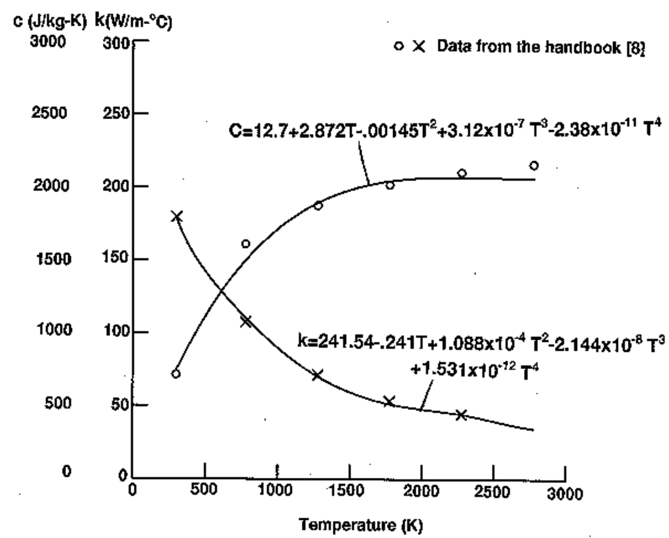
Heat capacity (symbol: C_p)—as distinct from **specific heat capacity**—is the measure of the heat energy rec
value is proportional to the amount of material in the object; for example, a bathtub of water has a greater heat

Heat capacity is usually expressed in units of J K^{-1} (or J/K), subject to the caveats and exceptions detailed in
55-gallon drum has an average heat capacity of 347 kJ/K.

The uncertainty of an object's measured quantity is rarely better than one percent and this places an upper lim
to specify the defined state at which the measurement was made; e.g. "(25 °C, 100 kPa)." In most cases, it is
relative uncertainty that it renders this detail moot. An exception would be when an object has an accurately k
exception would be when the defined state varies significantly from standard conditions.

Table of specific heat capacities

Substance	Phase	C_p J g^{-1} K^{-1}	$C_{p,m}$ J mol^{-1} K^{-1}	C_v J mol^{-1} K^{-1}	Volumetric heat capacity J cm^{-3} K^{-1}
Air (Sea level, dry, 0 °C)	gas	1.0035	29.07	20.7643	
Air (typical room conditions[A])	gas	1.012	29.19	20.85	
Aluminium	solid	0.897	24.2		2.422
Ammonia	liquid	4.700	**80.08**		3.263
Antimony	solid	0.207	25.2		1.386
Argon	gas	0.5203	20.7862	12.4717	
Arsenic	solid	0.328	24.6		1.878
Beryllium	solid	1.82	16.4		3.367



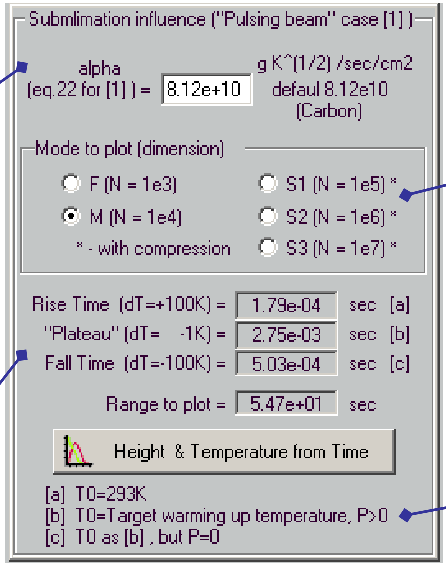
C.Liaw et al., Proceedings of the 1999 PAC, New York, p.3300

Dialog : Sublimation [1]

Integration of stiff set of differential equations (temperature and thickness) by Runge-Kutta method

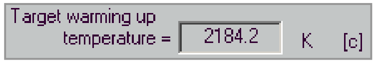
$$\frac{dT}{dt} = \frac{1}{C(T)h(t)}[P(t) + 2\varepsilon\sigma_0 T_0^4 - 2\varepsilon\sigma_0 T^4(t)\ ]$$

$$\frac{dh(t)}{dt} = -8.12\times 10^{10}\frac{\exp[\frac{-83\,500}{T}]}{\sqrt{T}}$$



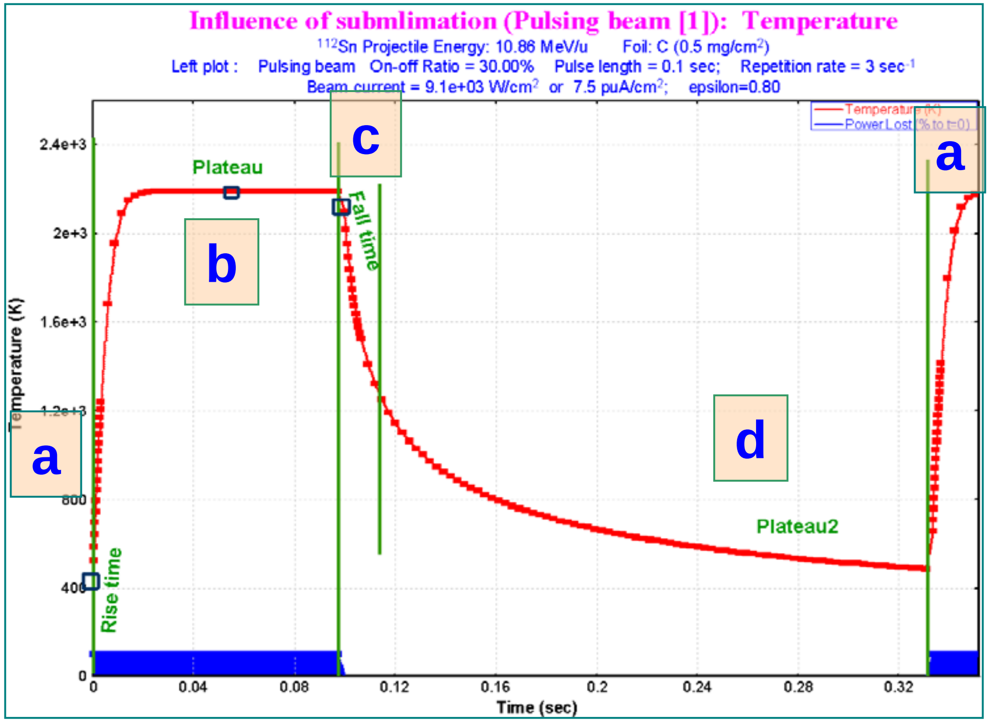
N : LISE++ distribution dimension.
How many points will be used for integration

S1 : only each 10th calculated point will be plotted
S2 : only each 100th point
S3 : only each 1000th point



4 integration region with different steps in order to

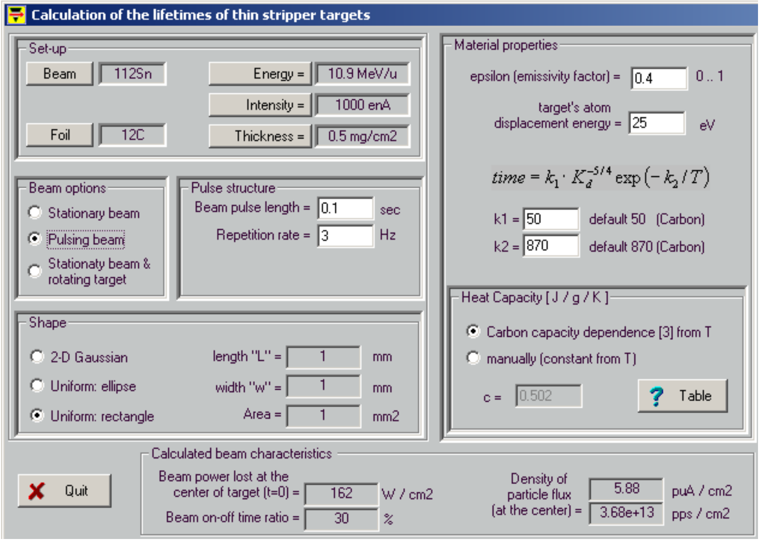
- *Make faster, plot more pulses*
- *and in the same time avoid unstable behavior*



Dialog : Sublimation [1] – modes to plot

	Range to plot (sec)	
Mode	Stationary	Pulsing (30% on-off time ratio)
F	7.59E+00	3.00E+00
M	7.79E+01	2.87E+01
S1	7.82E+02	2.69E+02
S2	7.82E+03	2.69E+03
S3	7.82E+04	2.69E+04
Lifetime	6.80E+03	~ 3E+04

Settings



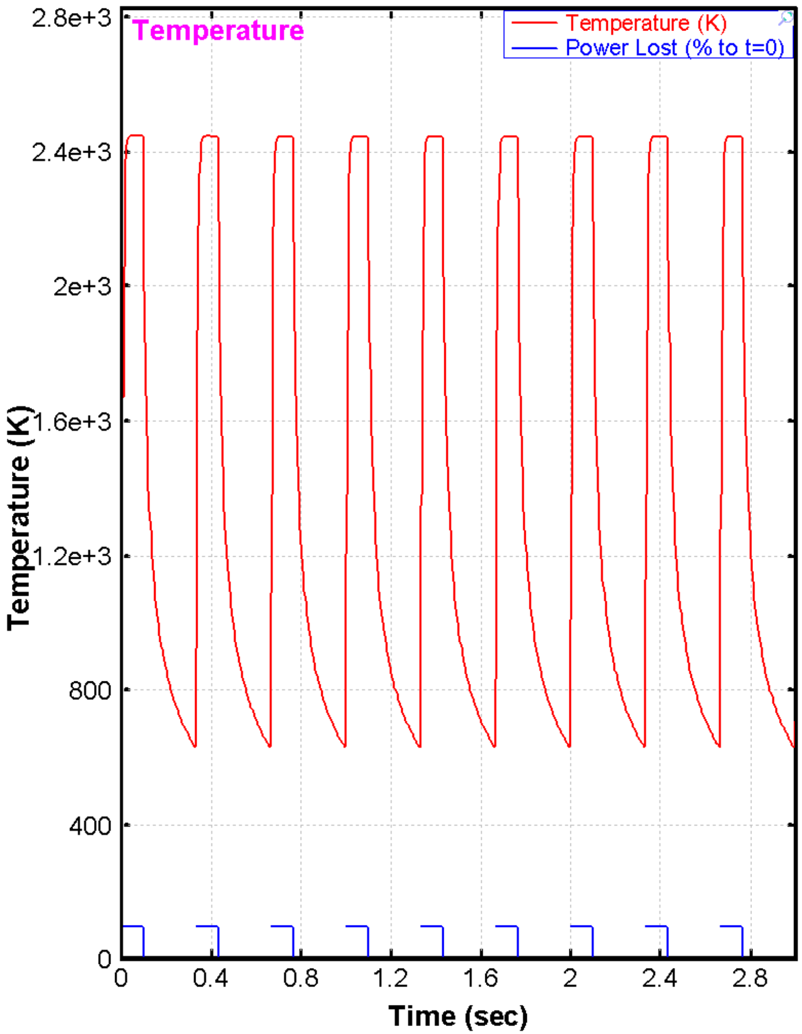
Influence of submlimation (Pulsing beam [1])

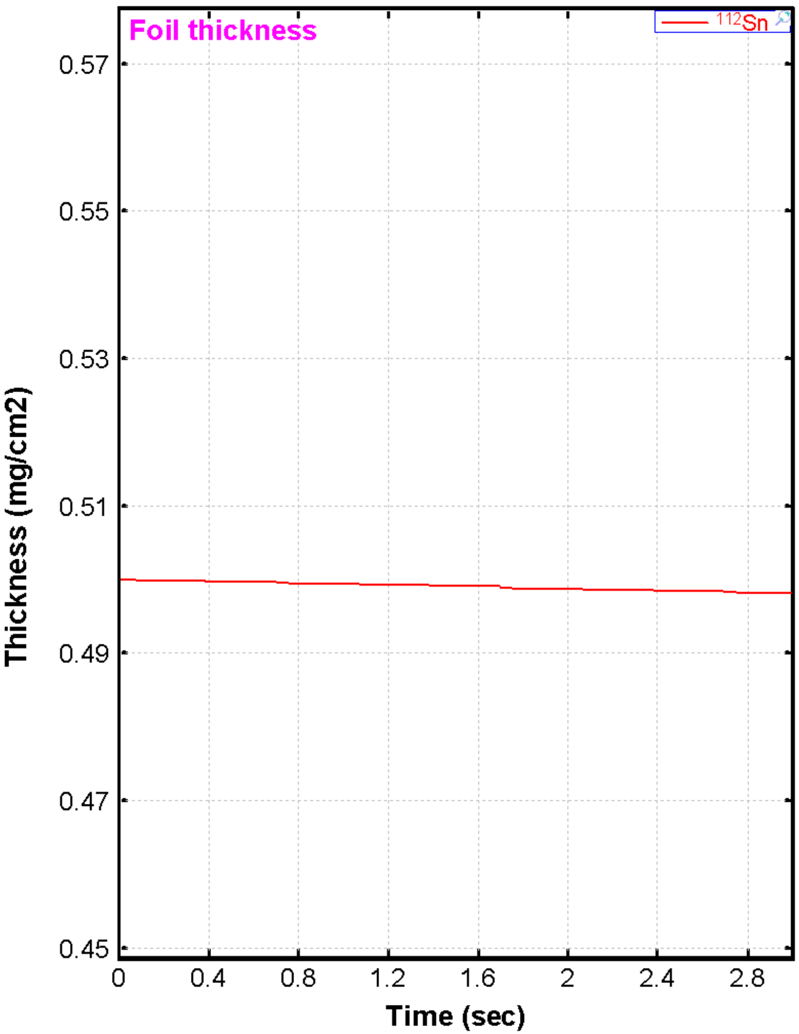
^{112}Sn Projectile Energy: 10.86 MeV/u Foil: C (0.5 mg/cm^2)

Left plot : Pulsing beam On-off Ratio = 30.00% Pulse length = 0.1 sec; Repetition rate = 3 sec^{-1}

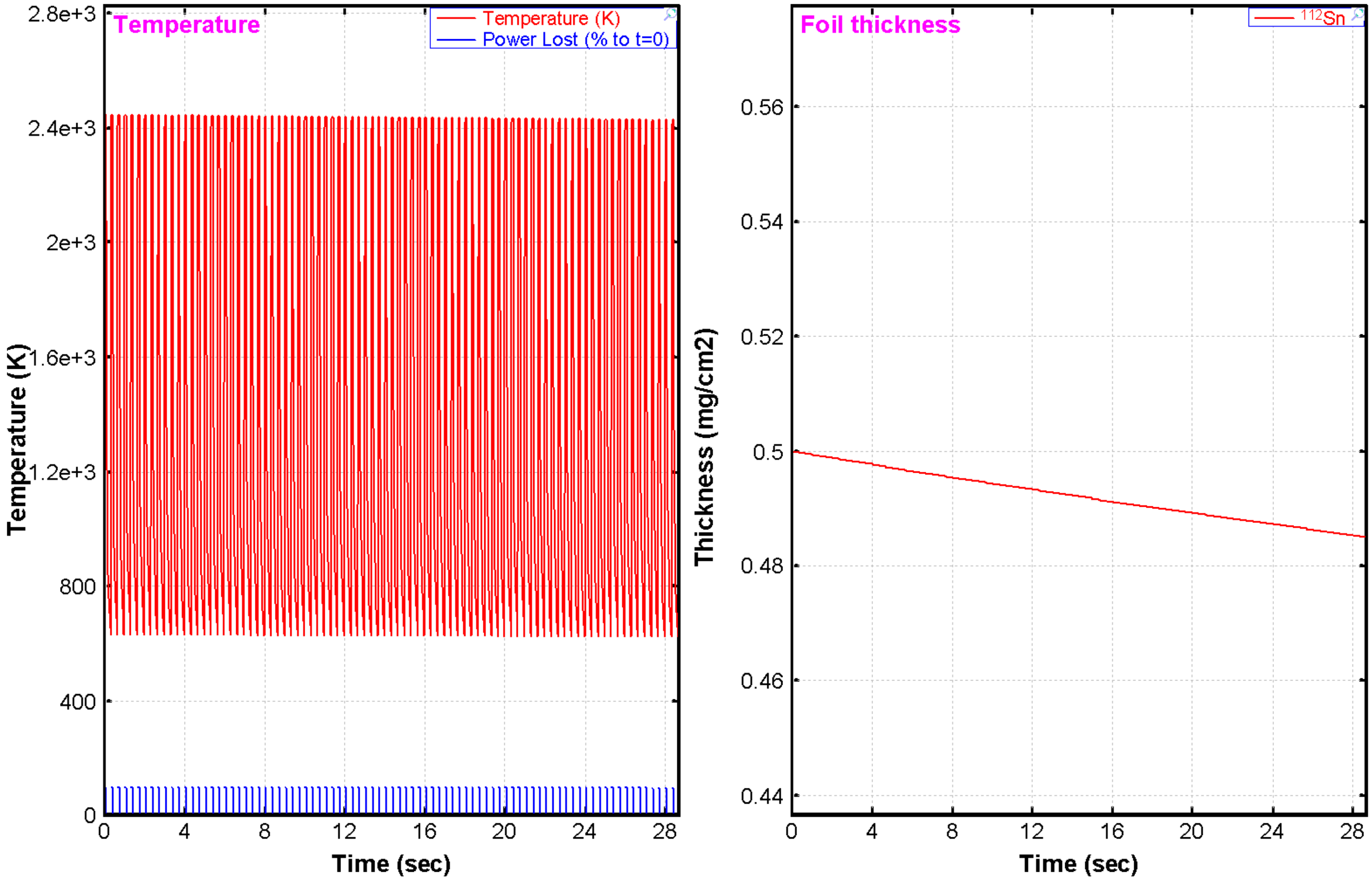
Beam current = 7.2e+03 W/cm^2 or 5.9 puA/cm^2; epsilon=0.40

Dialog : Pulsing beam example – "F" mode

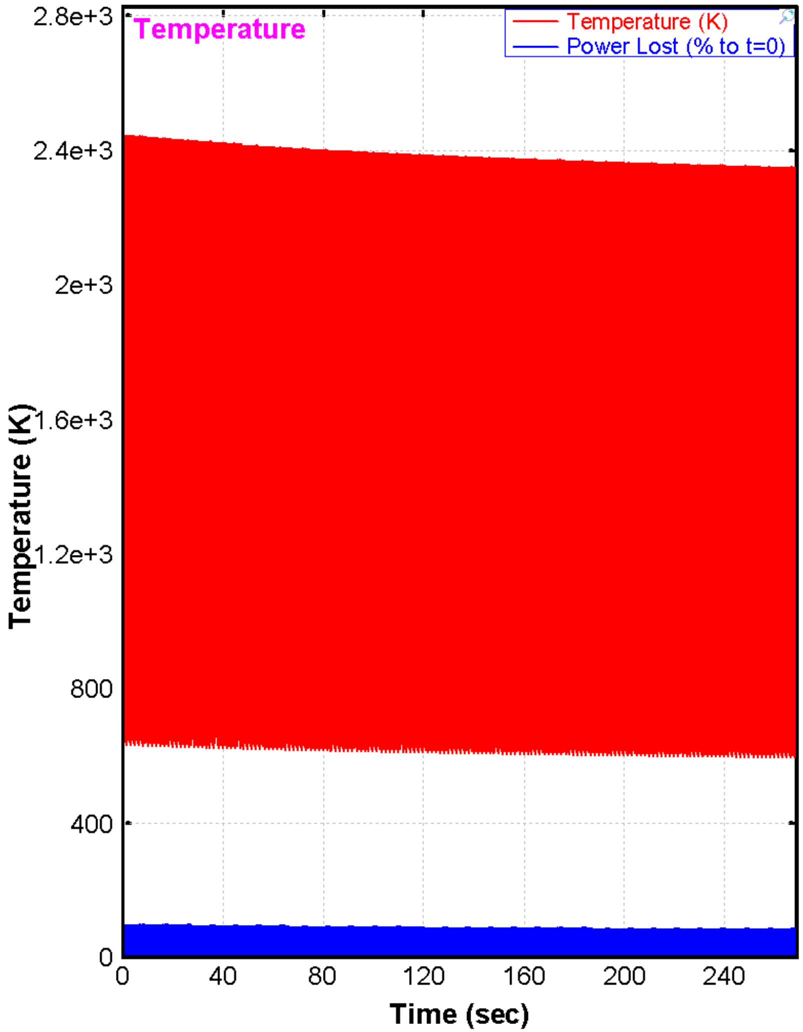


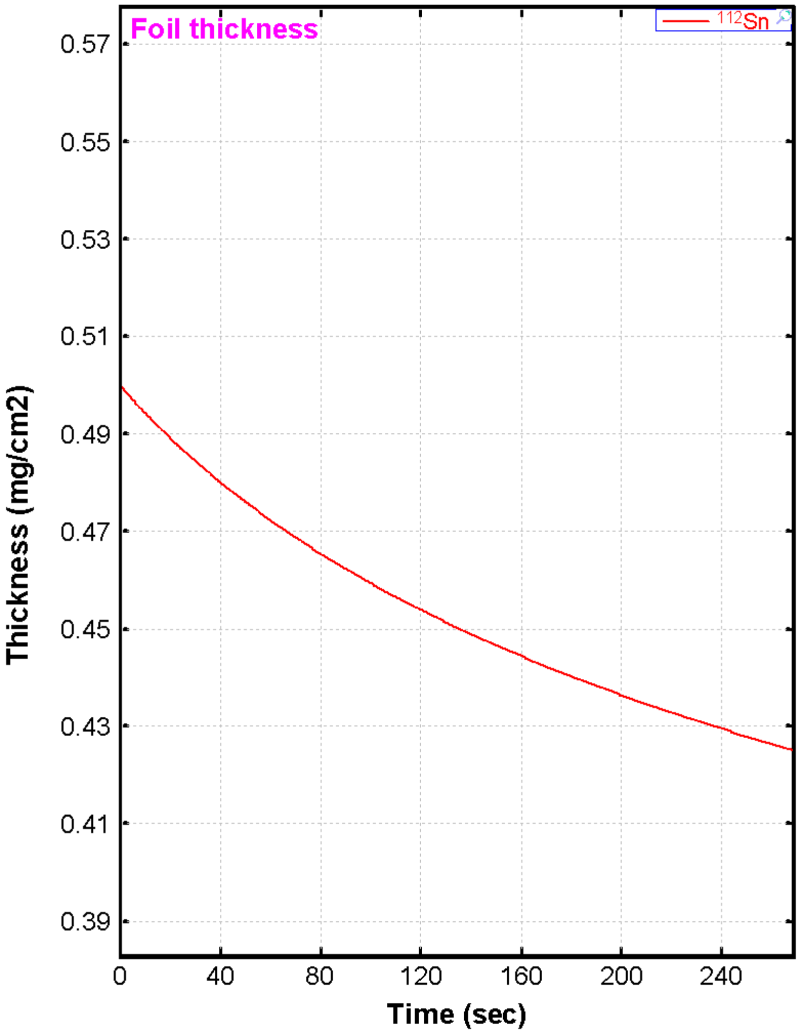


Dialog : Pulsing beam example – “M” mode

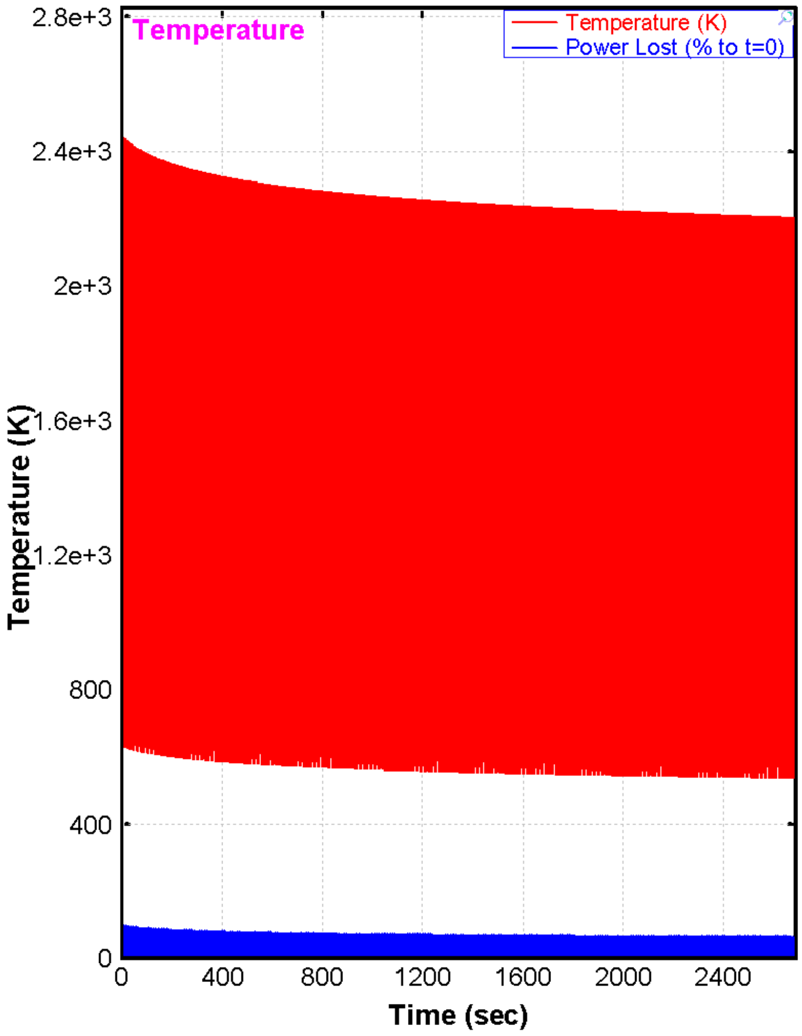


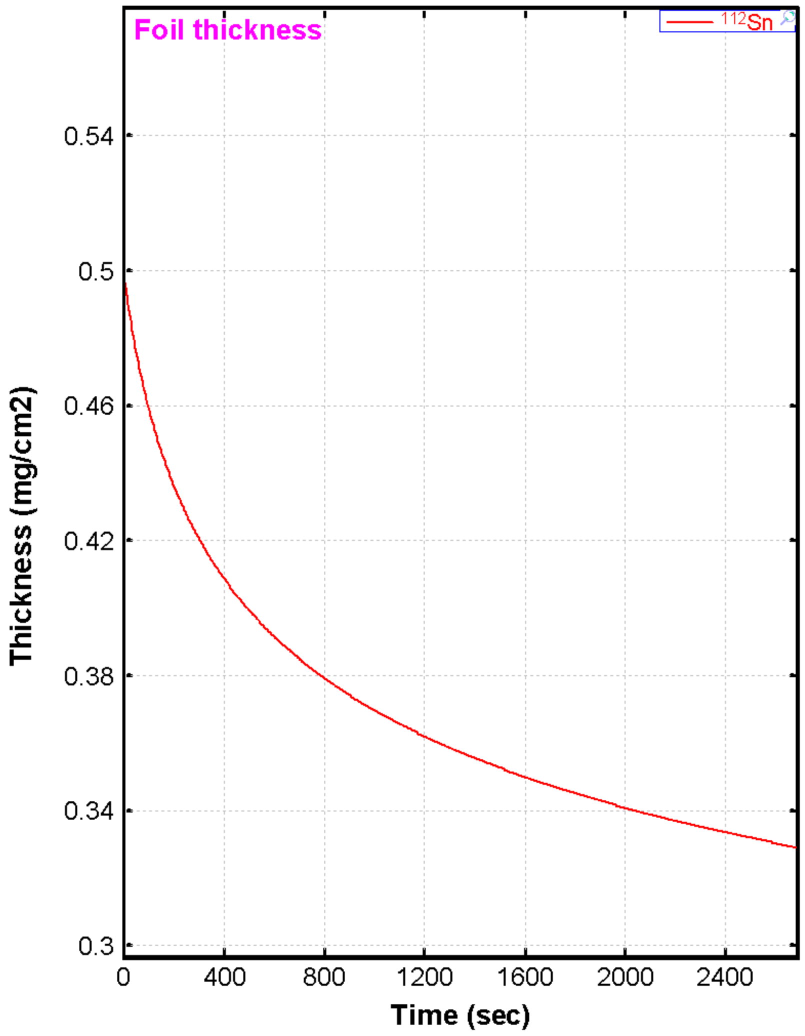
Dialog : Pulsing beam example – "S1" mode

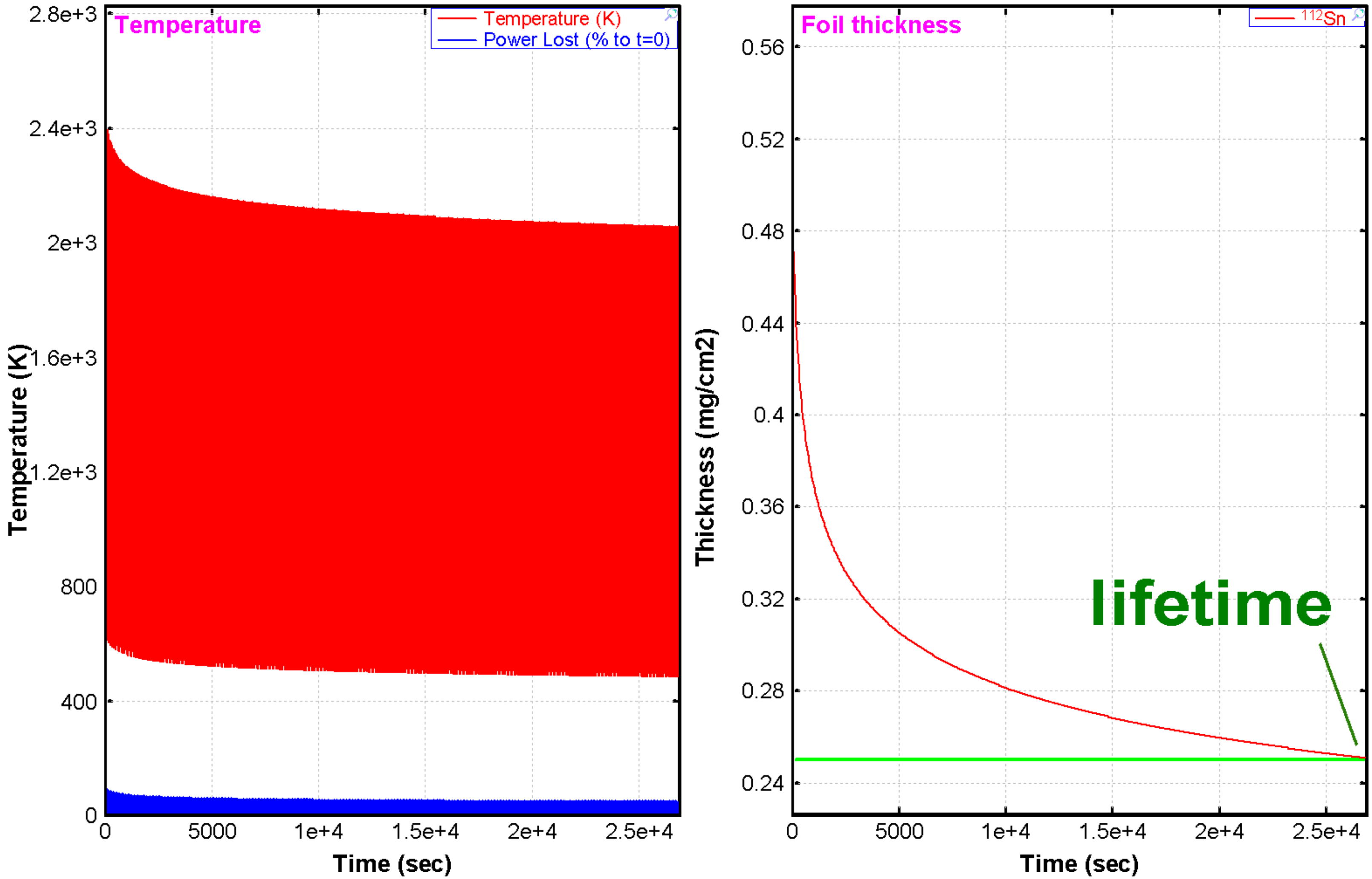




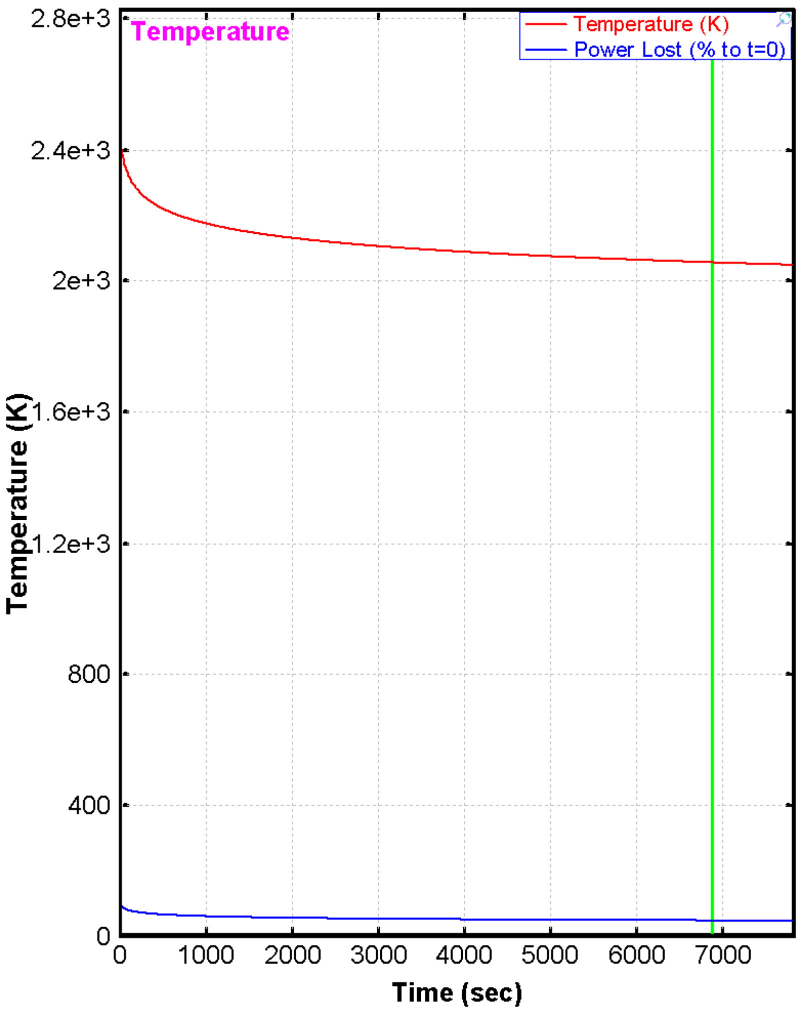
Dialog : Pulsing beam example – "S2" mode

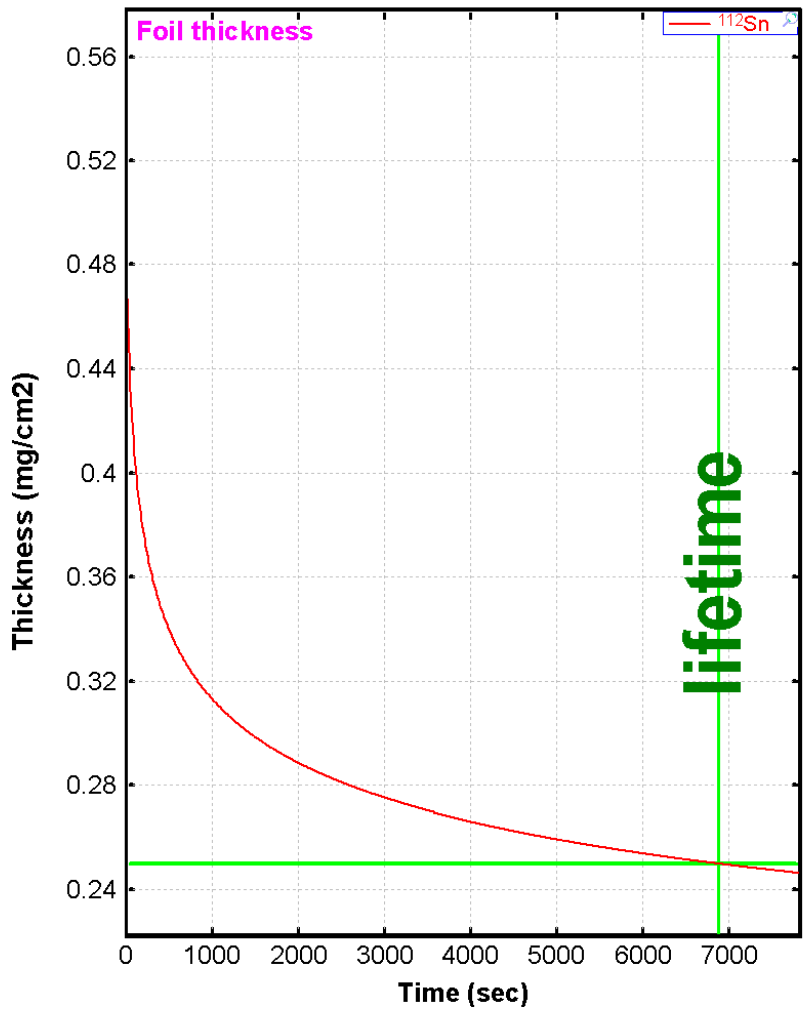




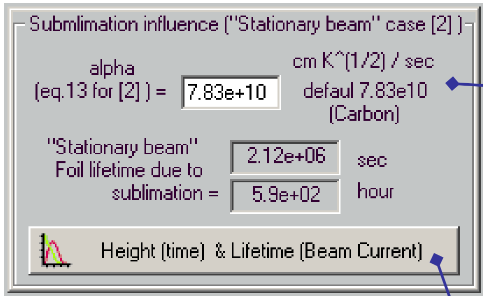

Temperature
Temperature (K)
Power Lost (% to t=0)
Temperature (K)
2.8e+3
2.4e+3
2e+3
1.6e+3
1.2e+3
800
400
0
0
5000
1e+4
1.5e+4
2e+4
2.5e+4
Time (sec)
Foil thickness
112Sn
Thickness (mg/cm2)
0.56
0.52
0.48
0.44
0.4
0.36
0.32
0.28
0.24
lifetime
Time (sec)

Dialog : Stationary beam example – “S2” mode





Dialog : Sublimation [2] v.8.3.5

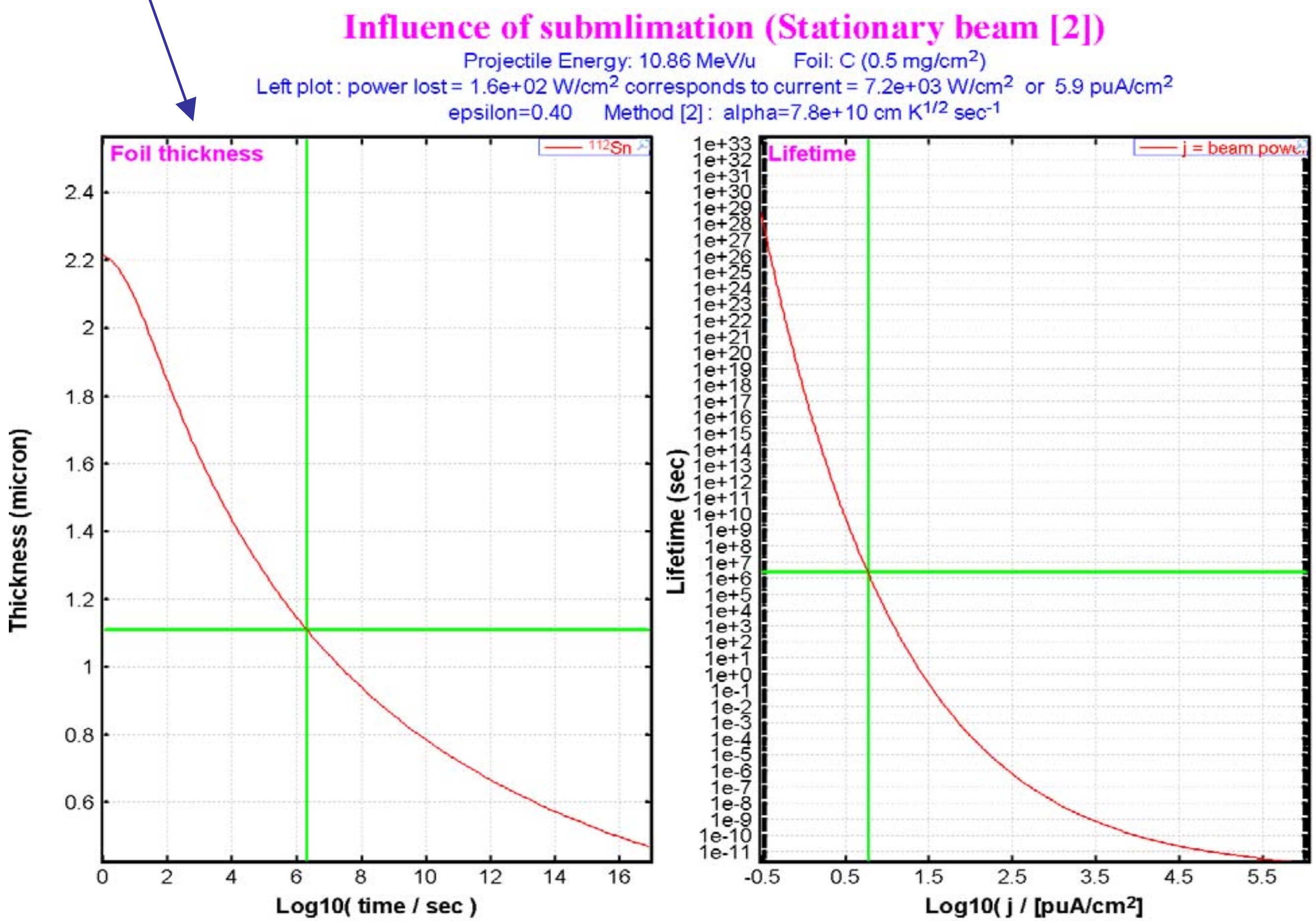


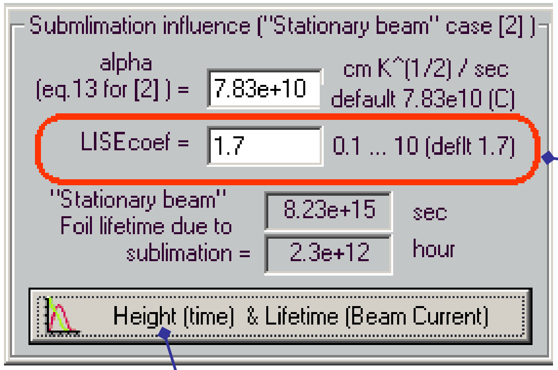
Integration by Euler's method with exponential step

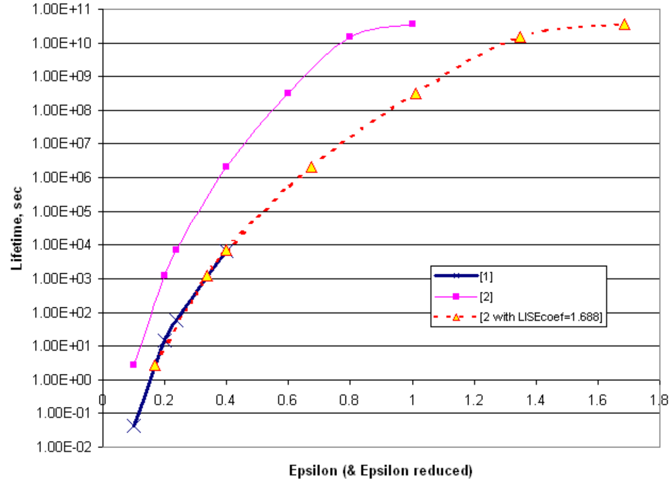
$$\frac{dh(t)}{dt} = -\alpha \cdot \frac{\exp\left(\frac{-B}{\beta\,\sqrt[4]{h(t)}}\right)}{\sqrt{\beta}\cdot\sqrt[8]{h(t)}},$$

where $\alpha = 0{,}242\,\frac{A\cdot\mu_c}{\rho\cdot\sqrt{M2}}$. In the case of carbon foil (μ_c=12 g/mol, ρ= 2 g/cm^3) is

$$\alpha \approx 7{,}83\cdot 10^{10}\left[cm\cdot K^{1/2}/s\right],\quad \beta = \sqrt[4]{\frac{P}{h_0\cdot\varepsilon\cdot\sigma_0\cdot 2}}\left[K\cdot cm^{-1/4}/s\right].$$



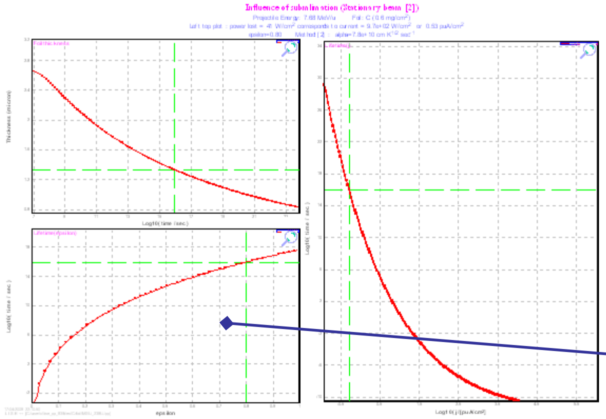


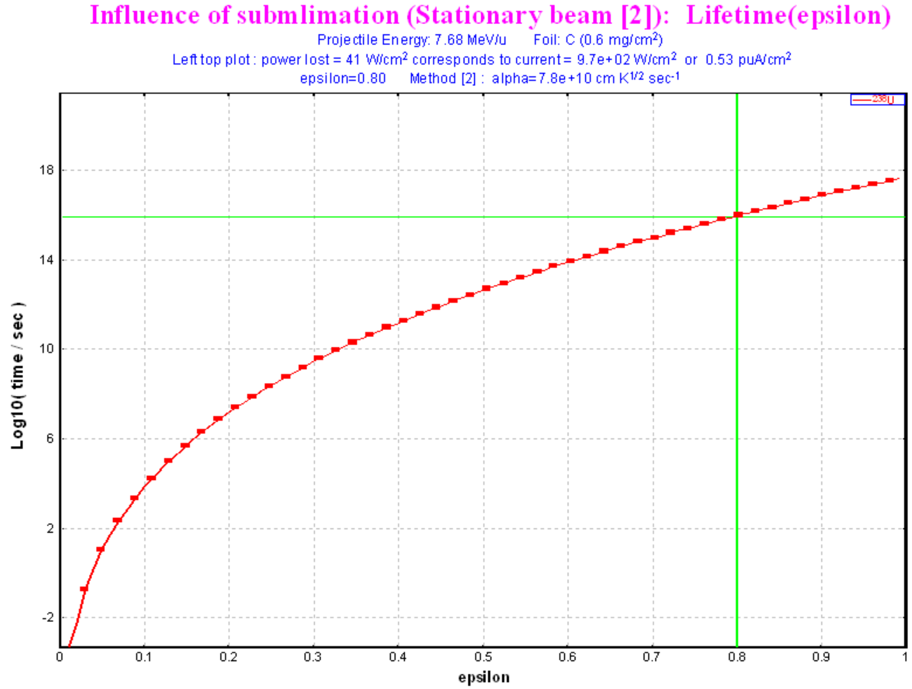


For agreement with [1]

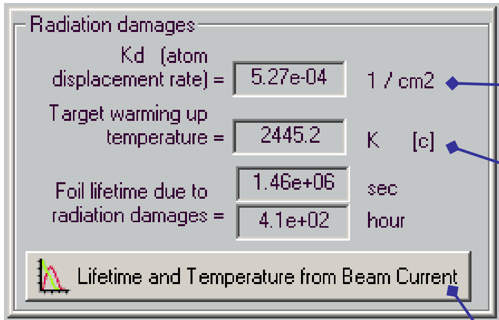
$$\beta = \sqrt[4]{\frac{P \cdot LISEcoef}{h_0 \cdot \varepsilon \cdot \sigma_0 \cdot 2}}$$

LISEcoef = 1.7





Dialog : Radiation damages



[1]'s algorithm was used

$$K_d = \frac{S_n \bar{\varphi}}{2E_D}, \qquad t = 50 K_d^{-(5/4)} \exp\left(-\frac{870}{T}\right).$$

$$T = \left(\frac{P}{2 \cdot \varepsilon \cdot \sigma_0} + T_0^4\right)^{1/4}$$

where P [W/cm^2] is the beam power lost in a target, calculated by means of the LISE++ code

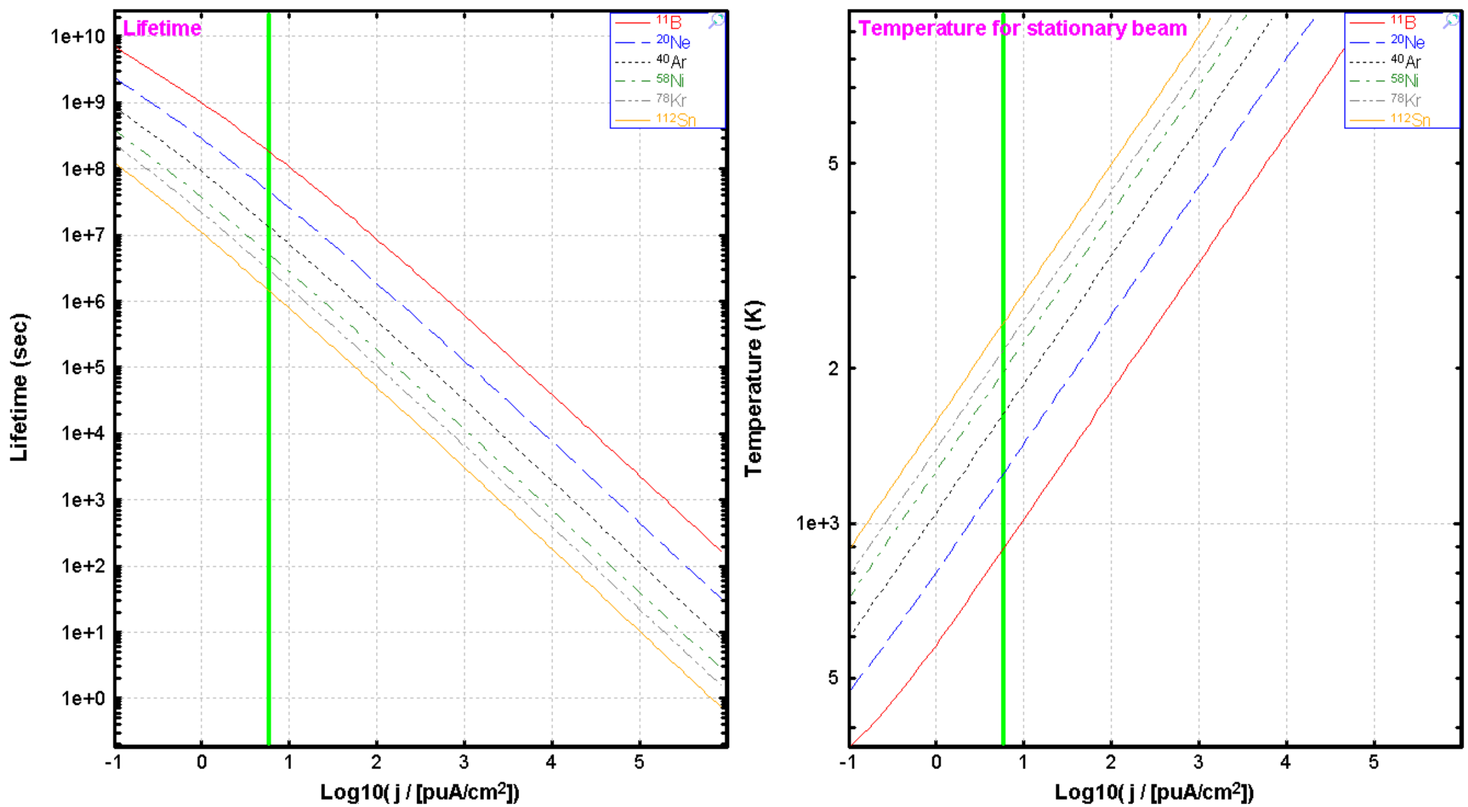
Beam on-off time ratio is applied for the Radiation damages lifetime as the normalization factor 1 / Ratio

Influence of radiation damages

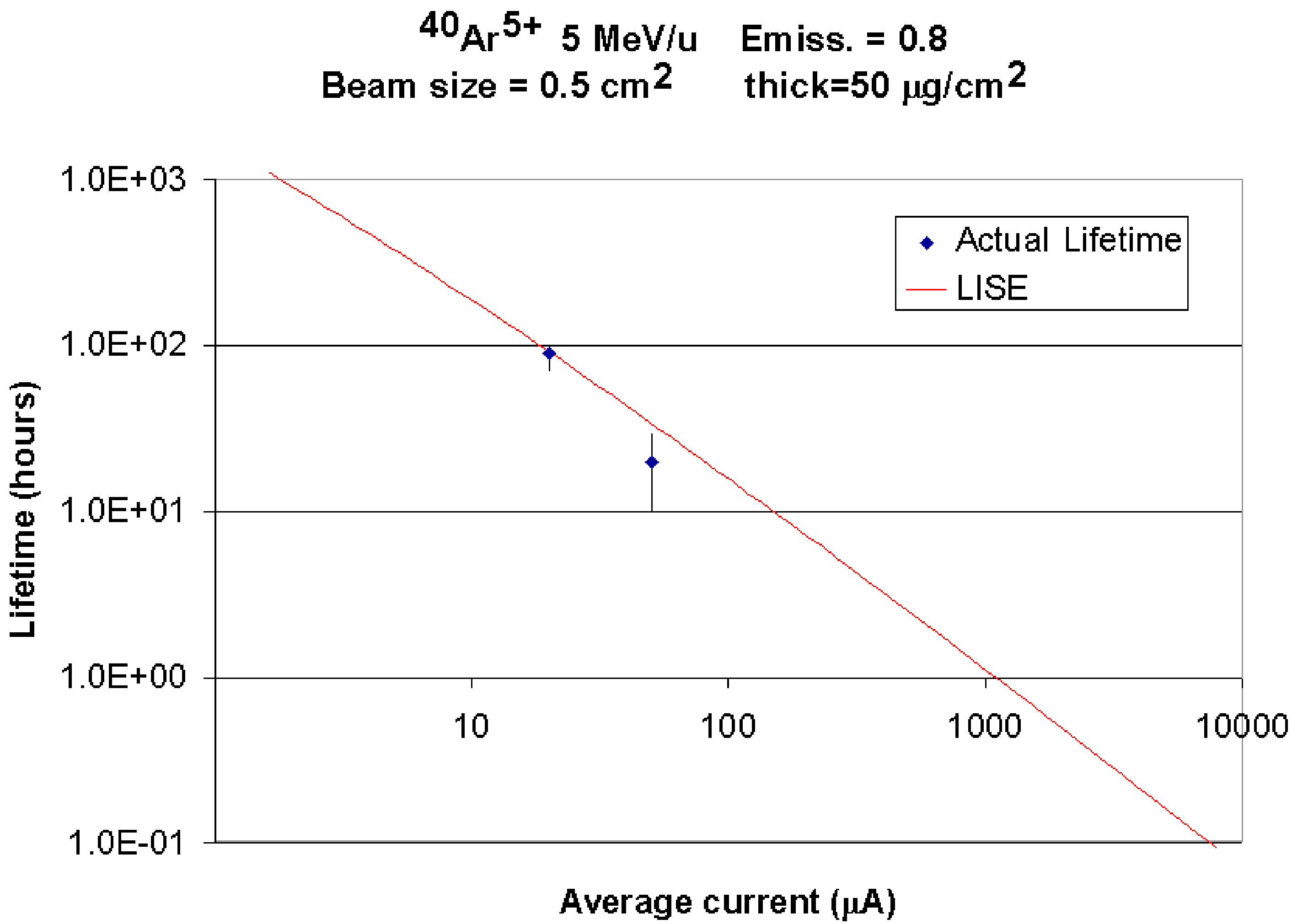
Projectile Energy: 10.86 MeV/u Foil: C (0.5 mg/cm^2)

Left plot : Pulsing beam On-off Ratio = 30.00% Pulse length = 0.1 sec; Repetition rate = 3 sec^{-1}

epsilon=0.40 Displacement Energy=25.0 k1=50.0 k2=870.0

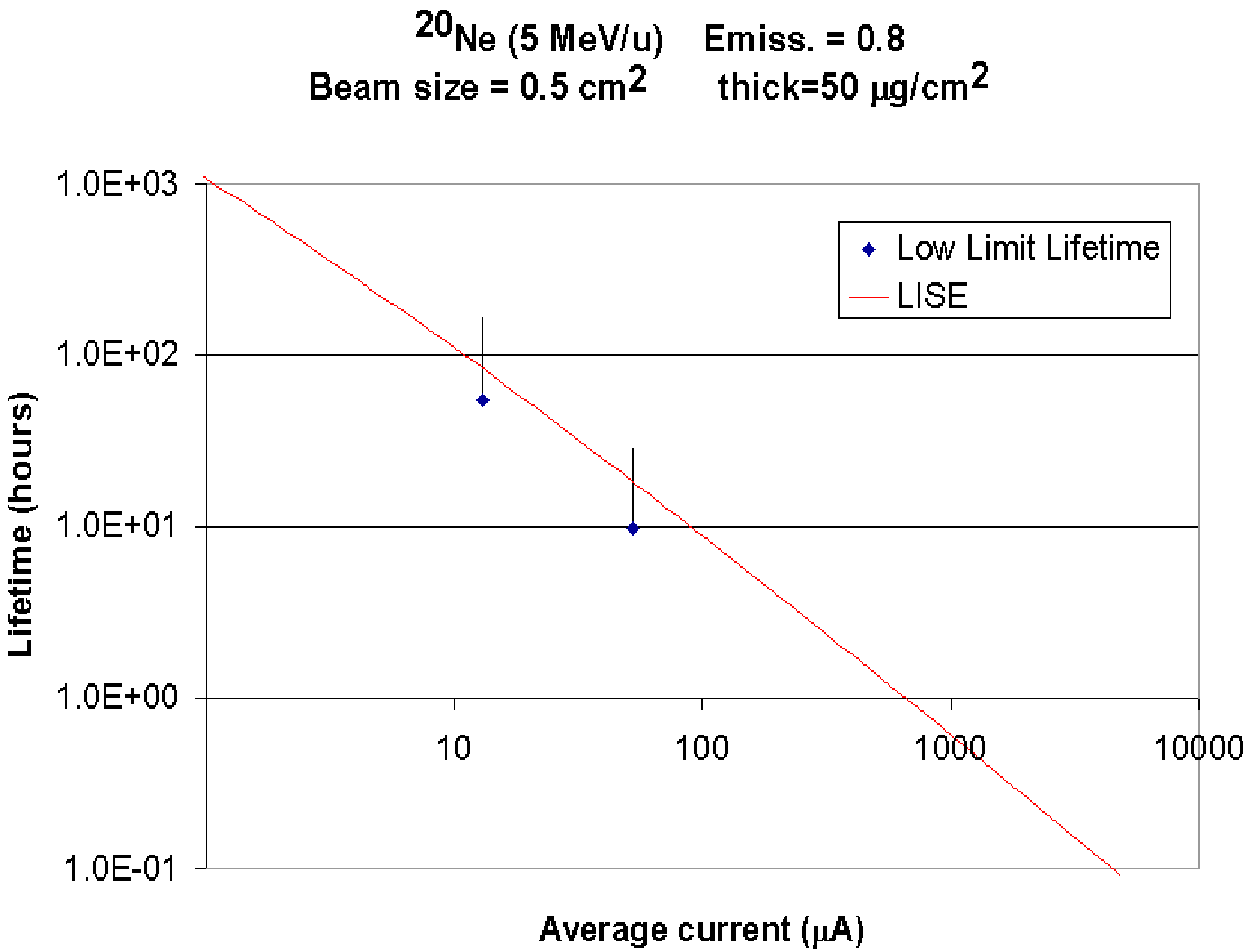


^{40}Ar @ Dubna : Radiation damages



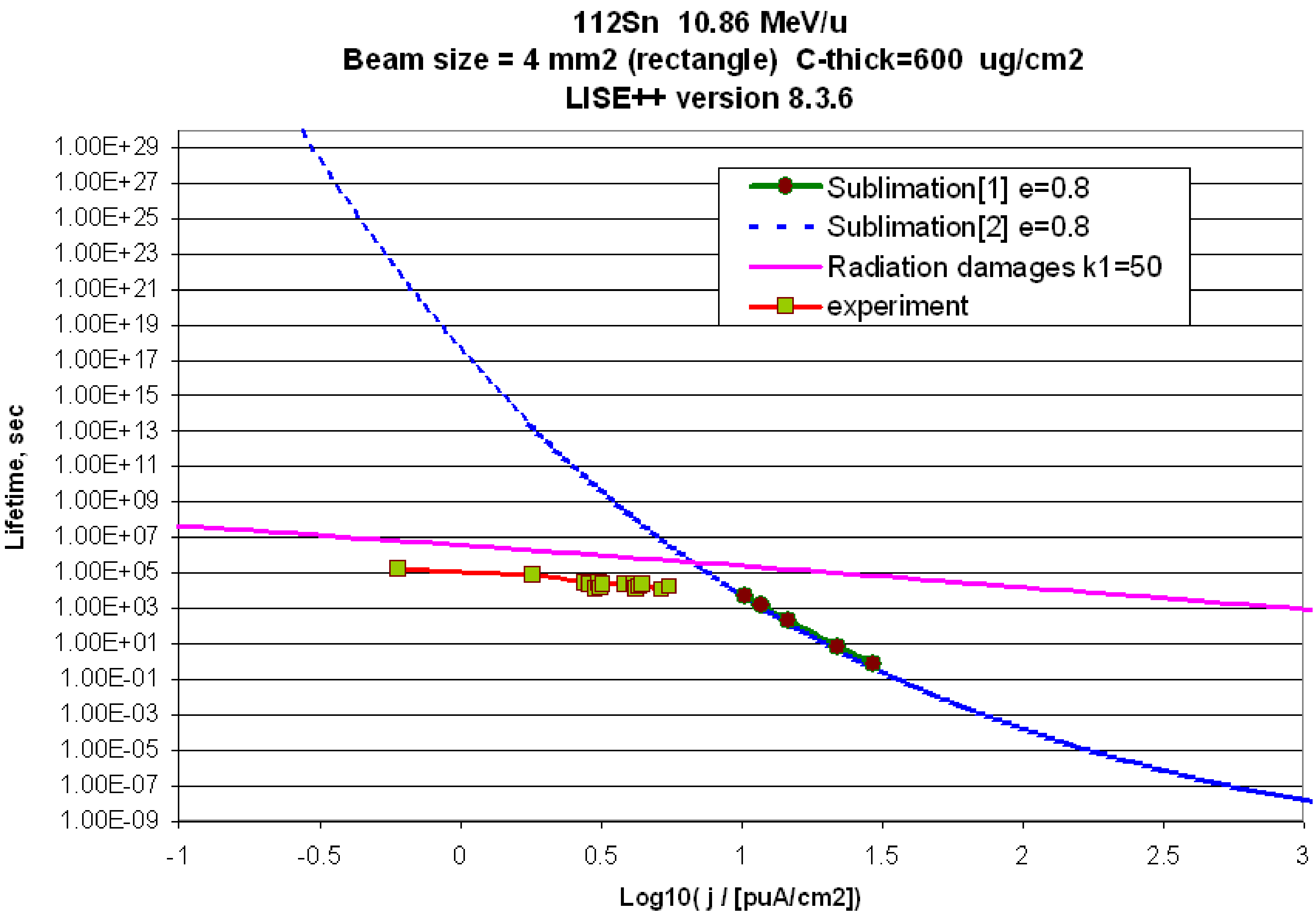
v.8.3.6 http://groups.nscl.msu.edu/lise/8_3/Dubna_40Ar.lpp
v.8.3.11 http://groups.nscl.msu.edu/lise/8_3/Dubna_40Ar.foil

^{20}Ne @ Dubna : Radiation damages

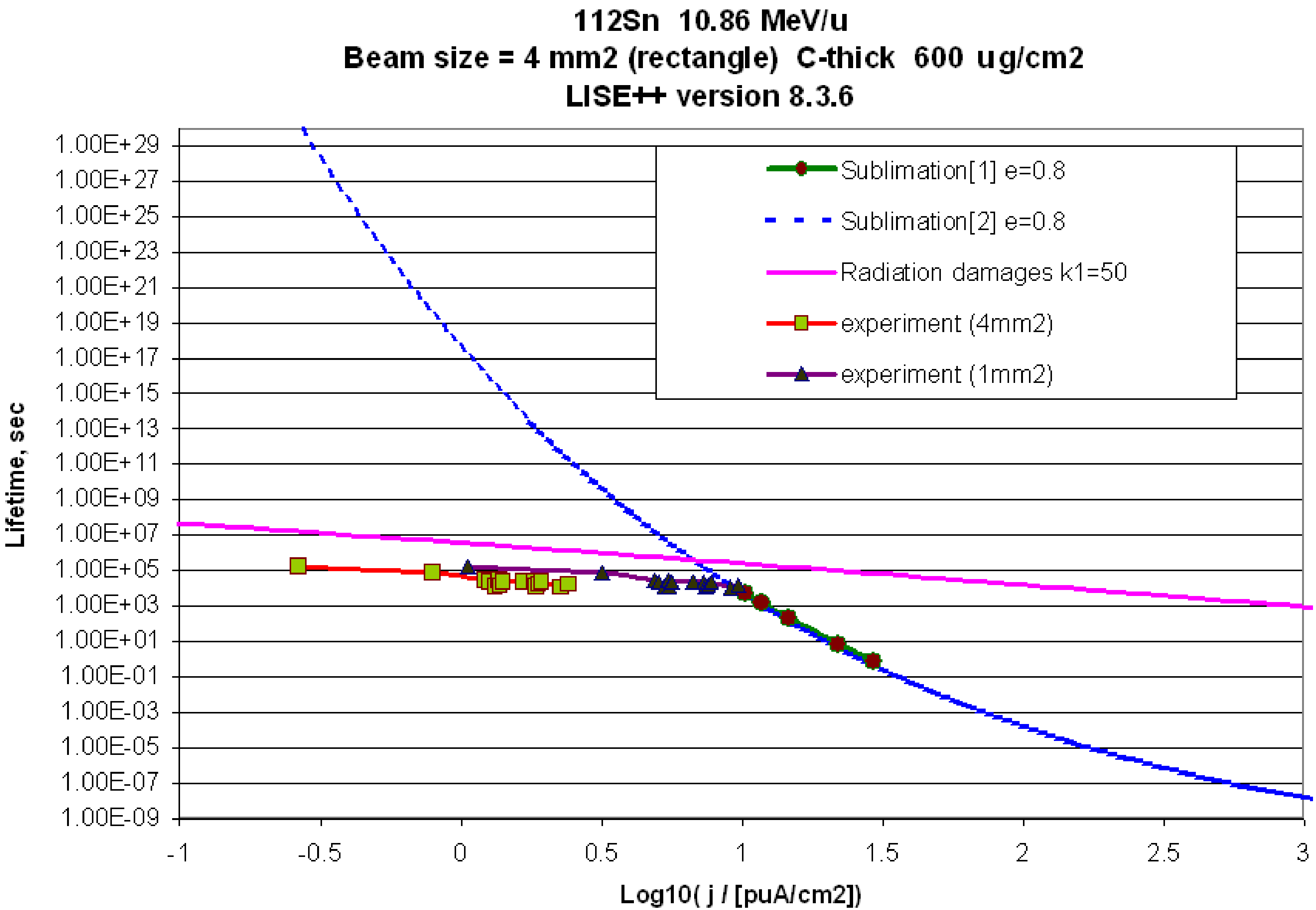


v.8.3.6 http://groups.nscl.msu.edu/lise/8_3/Dubna_20Ne.lpp
v.8.3.11 http://groups.nscl.msu.edu/lise/8_3/Dubna_20Ne.foil

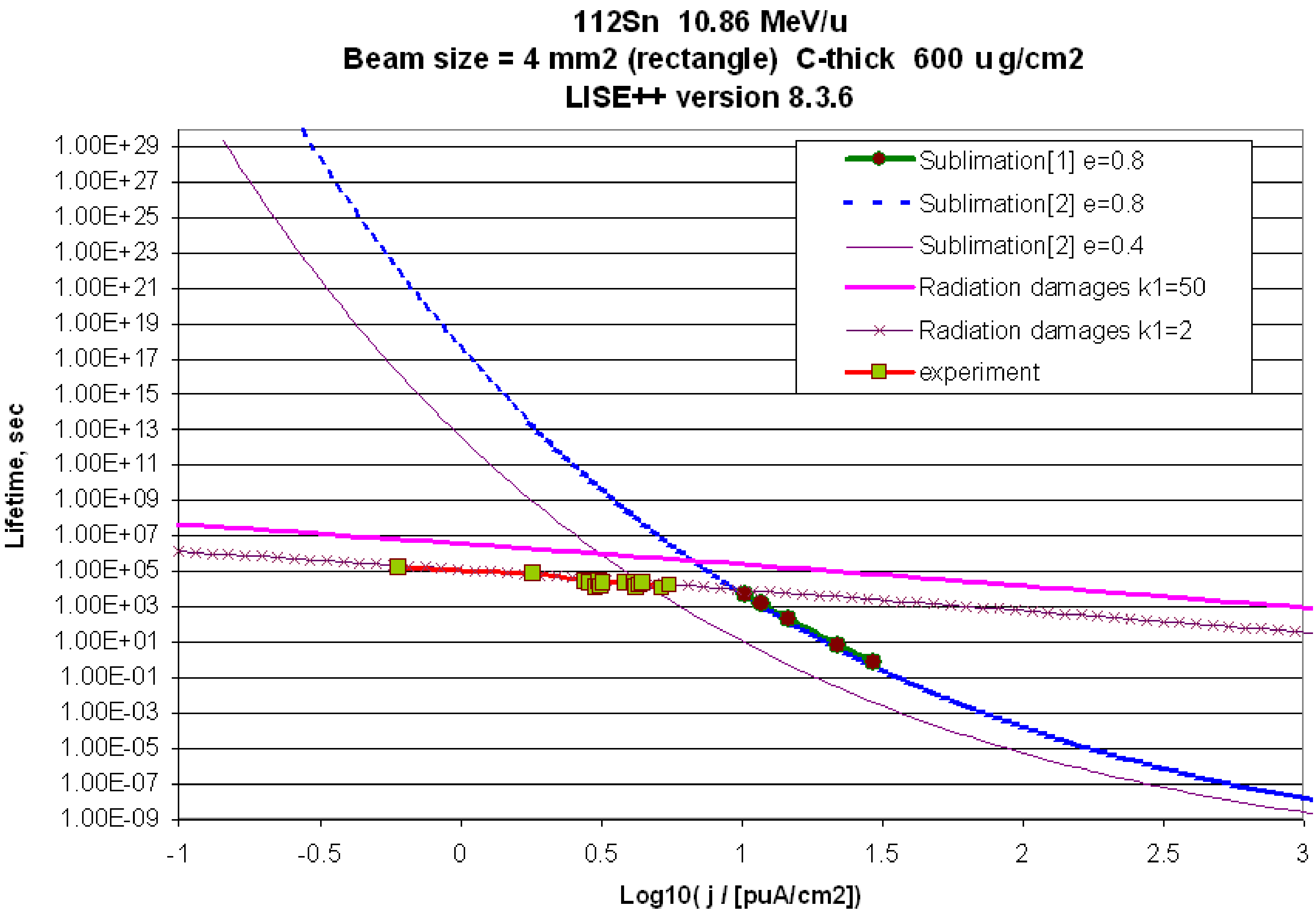
$^{112}Sn^{17+}$ 10.86 MeV/u @ MSU : Competition



v.8.3.6 http://groups.nscl.msu.edu/lise/8_3/MSU_112Sn.lpp
v.8.3.11 http://groups.nscl.msu.edu/lise/8_3/MSU_112Sn.foil

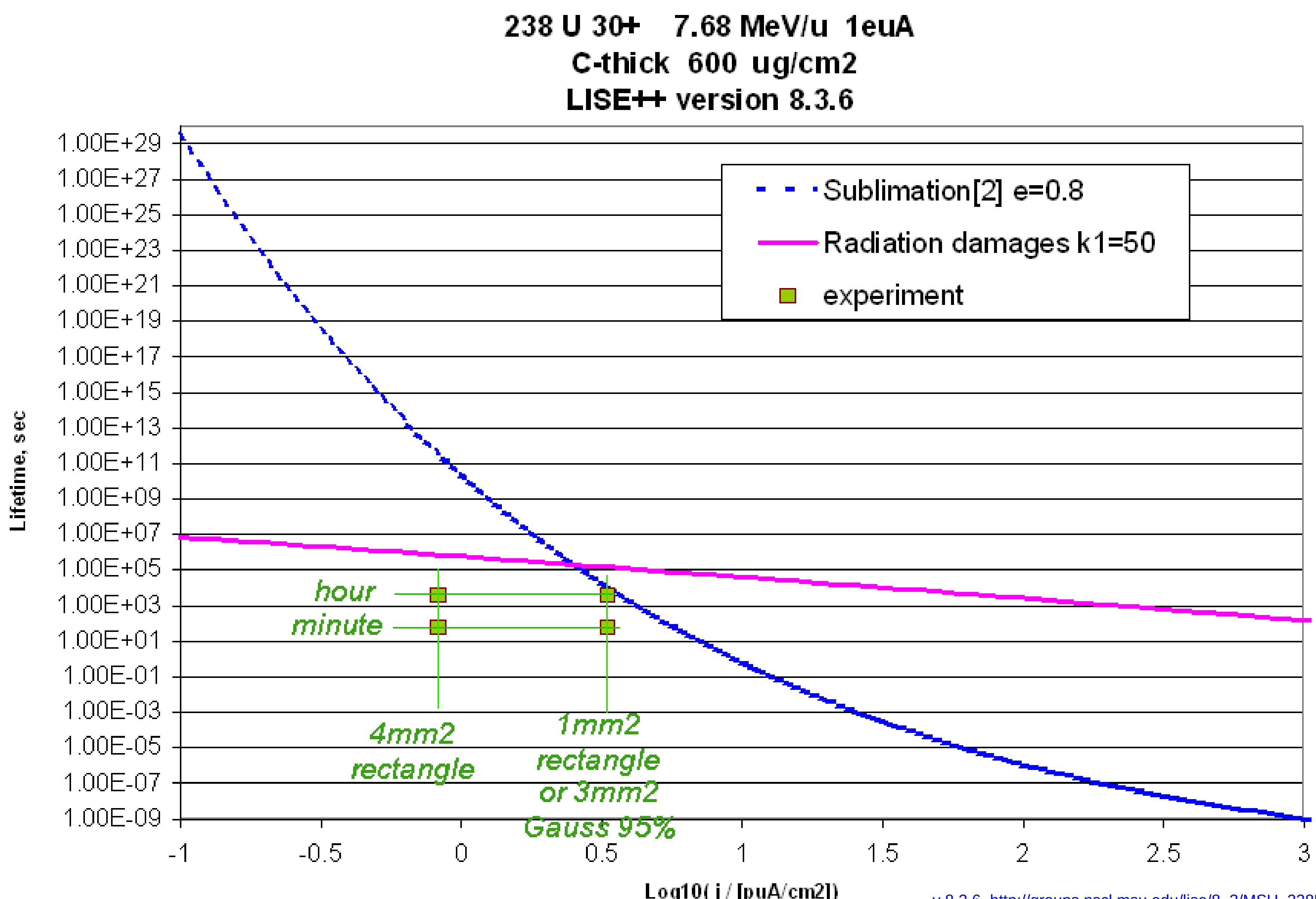

112Sn 10.86 MeV/u
Beam size = 4 mm2 (rectangle) C-thick 600 ug/cm2
LISE++ version 8.3.6
Sublimation[1] e=0.8
Sublimation[2] e=0.8
Radiation damages k1=50
experiment (4mm2)
experiment (1mm2)
Lifetime, sec
1.00E+29
1.00E+27
1.00E+25
1.00E+23
1.00E+21
1.00E+19
1.00E+17
1.00E+15
1.00E+13
1.00E+11
1.00E+09
1.00E+07
1.00E+05
1.00E+03
1.00E+01
1.00E-01
1.00E-03
1.00E-05
1.00E-07
1.00E-09
-1
-0.5
0
0.5
1
1.5
2
2.5
3
Log10(j / [puA/cm2])

$^{112}Sn^{17+}$ 10.86 MeV/u @ MSU : Radiation damage



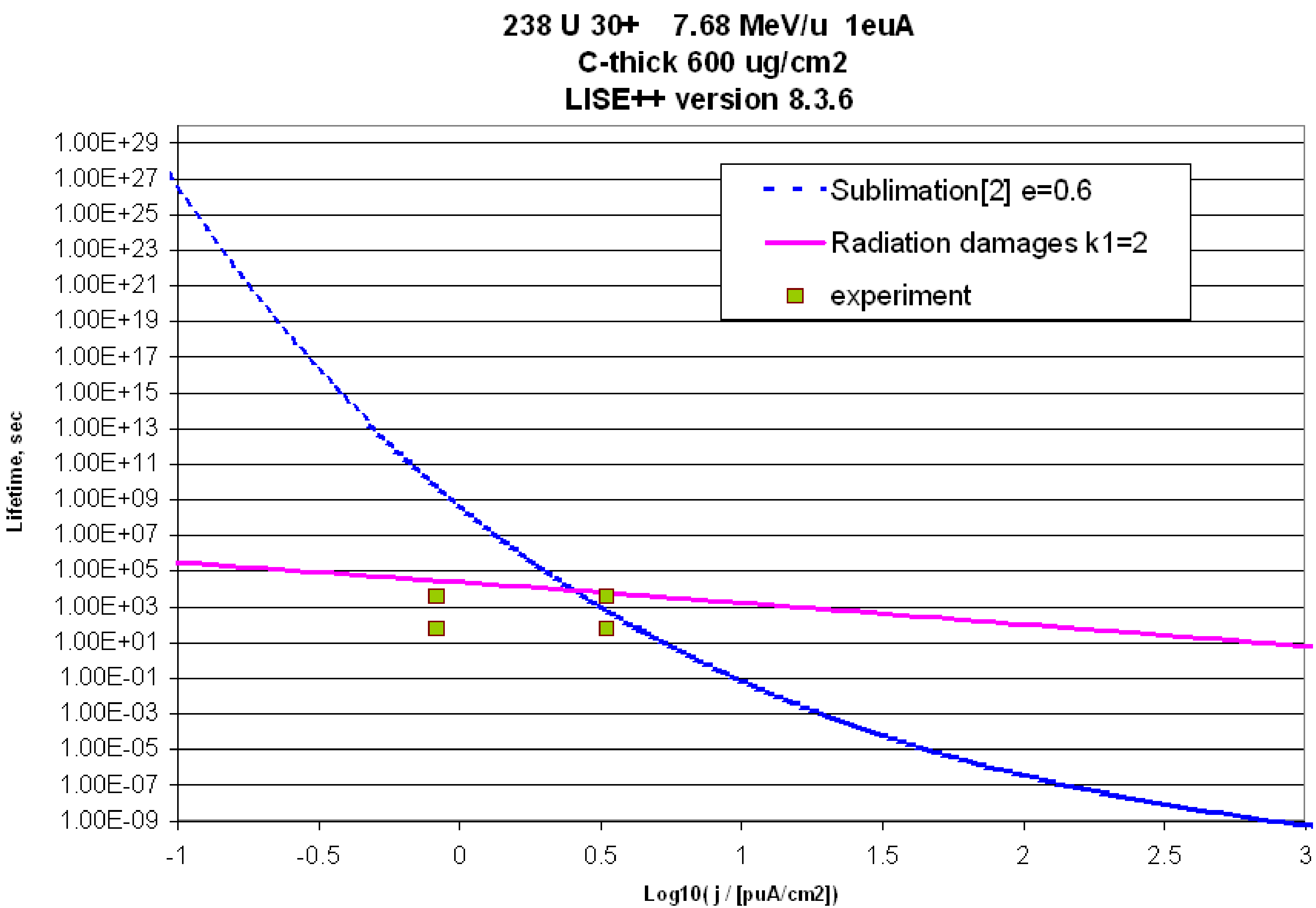
F.Marti: radiation damage has proved experimentally

$^{238}U^{30+}$ 7.68 MeV/u @ MSU : ?



v.8.3.6. http://groups.nscl.msu.edu/lise/8_3/MSU_238U.lpp
v.8.3.11. http://groups.nscl.msu.edu/lise/8_3/MSU_238U.foil

$^{238}U^{30+}$ 7.68 MeV/u @ MSU : ?



$^1H^-$ 750 KeV 2.0mA @ BNL : Sublimation

TABLE I. The parameters of H^- beams

	Energy	Duration of an impulse	Frequency	The maximal current	The beam size
BNL linac	750 keV	0.5 ms	6.7 Hz	2.02/2.2 mA	3 mm diameter

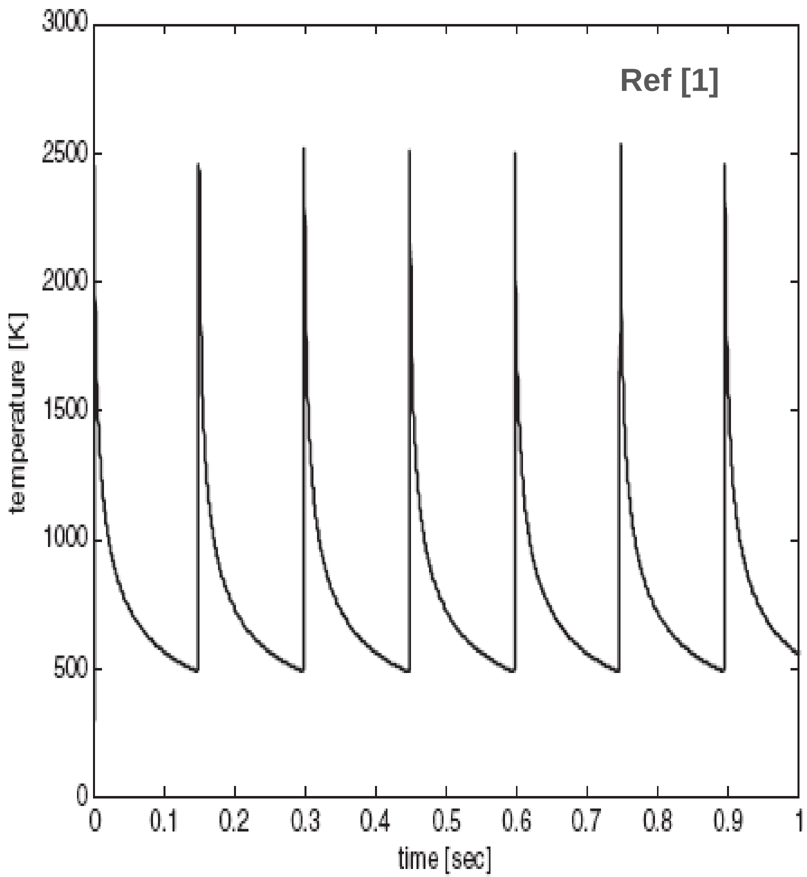


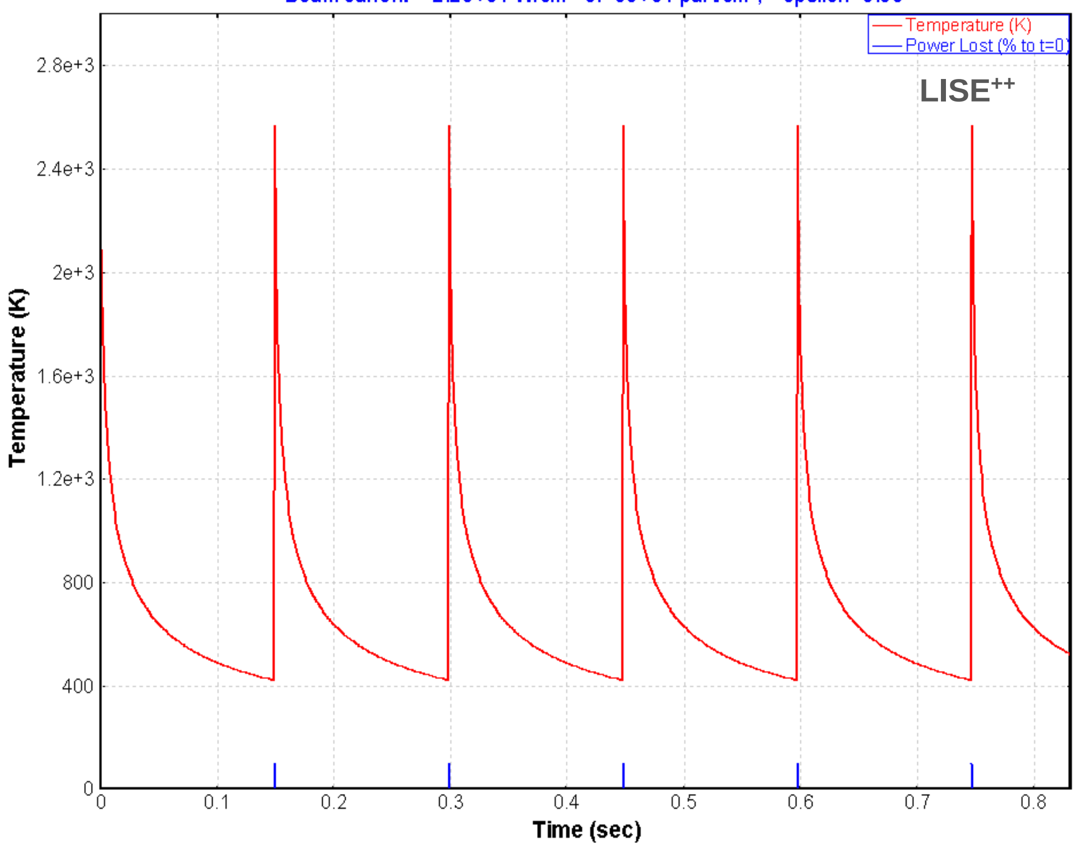
FIG. 1. A temperature field of a BNL linac target in the first second of work at a pulse current of 2 mA.

Influence of submlimation (Pulsing beam [1]): Temperature

^{1}H Projectile Energy: 0.75 MeV/u Foil: C (0.23 mg/cm^2)

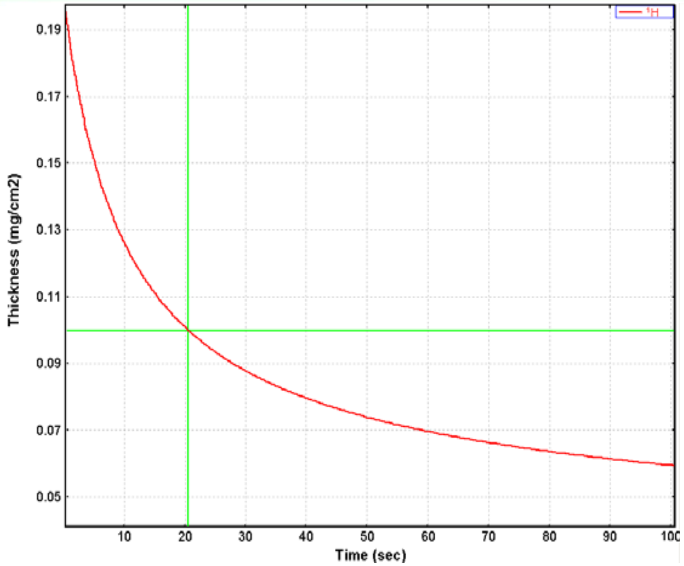
Left plot : Pulsing beam On-off Ratio = 0.34% Pulse length = 0.0005 sec; Repetition rate = 6.7 sec^{-1}

Beam current = 2.2e+04 W/cm^2 or 3e+04 puA/cm^2; epsilon=0.80

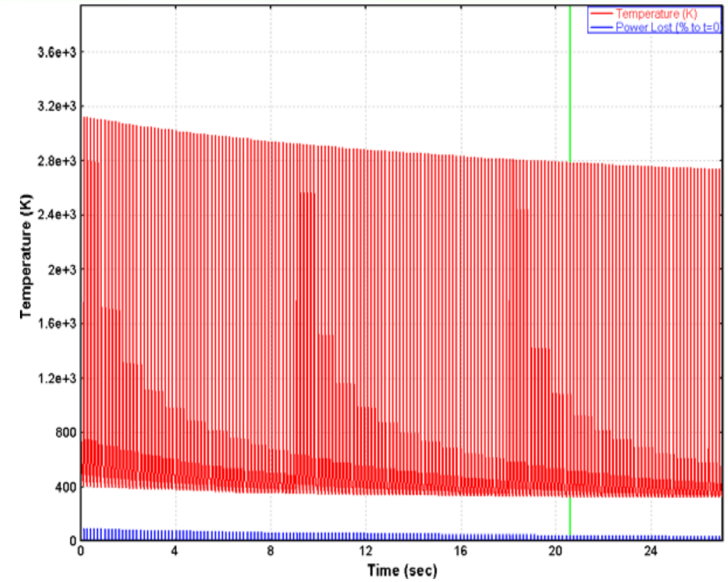


v.8.3.11 http://groups.nscl.msu.edu/lise/8_3/BNL_H_750KeV_2mA.foil

$^1H^-$ 750 KeV 3mA @ BNL : Sublimation



LISE++



Ref [1]

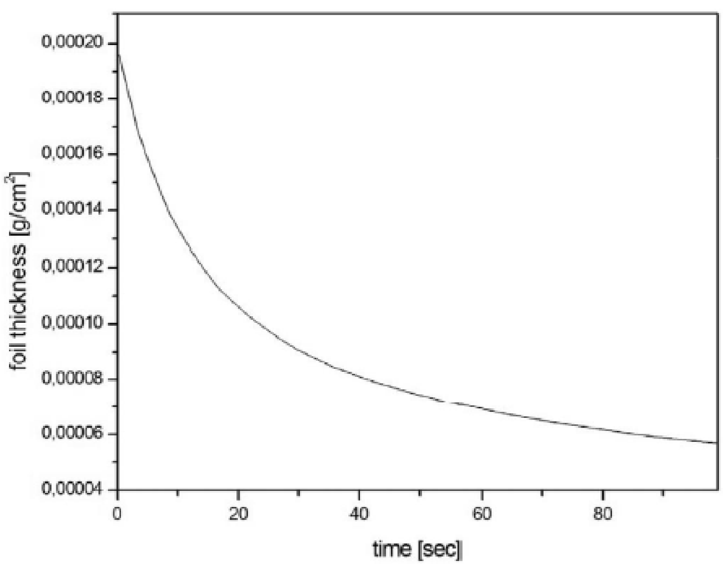


FIG. 2. Nonlinear foil thickness decreasing caused by the reduction of temperature at the BNL linac pulse current of 3 mA.

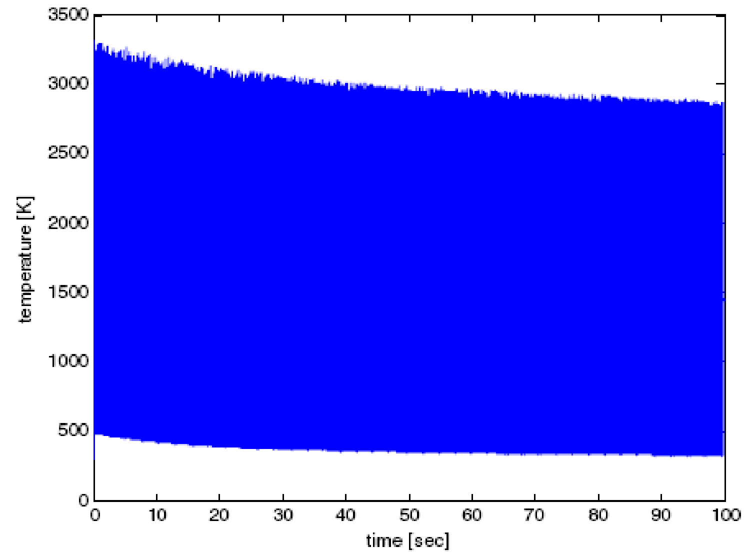
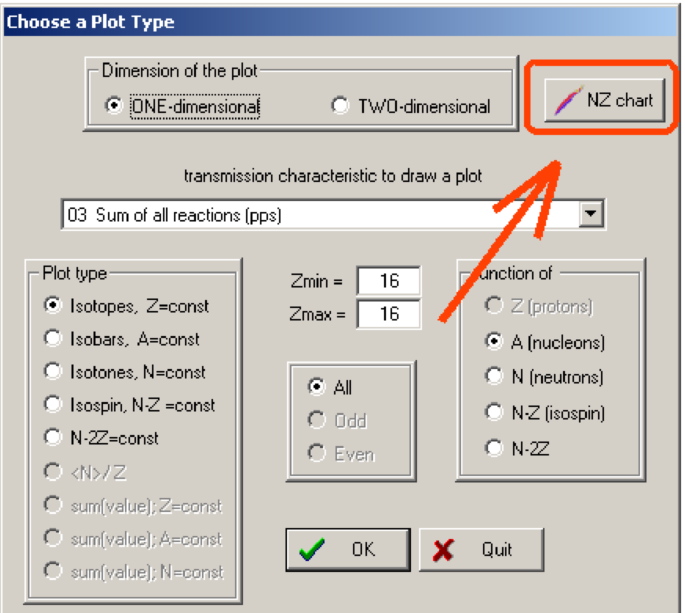
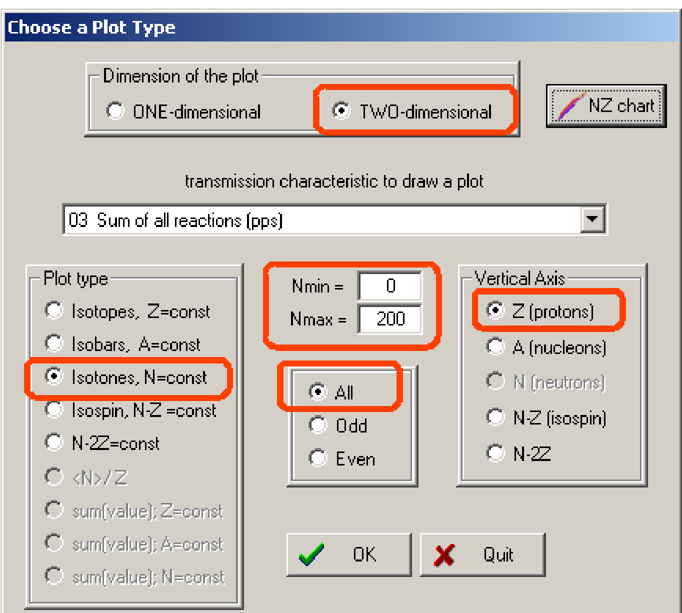


FIG. 3. (Color) Deformation of a temperature field in a target of BNL linac, caused by the decreasing of the foil thickness due to its evaporation.

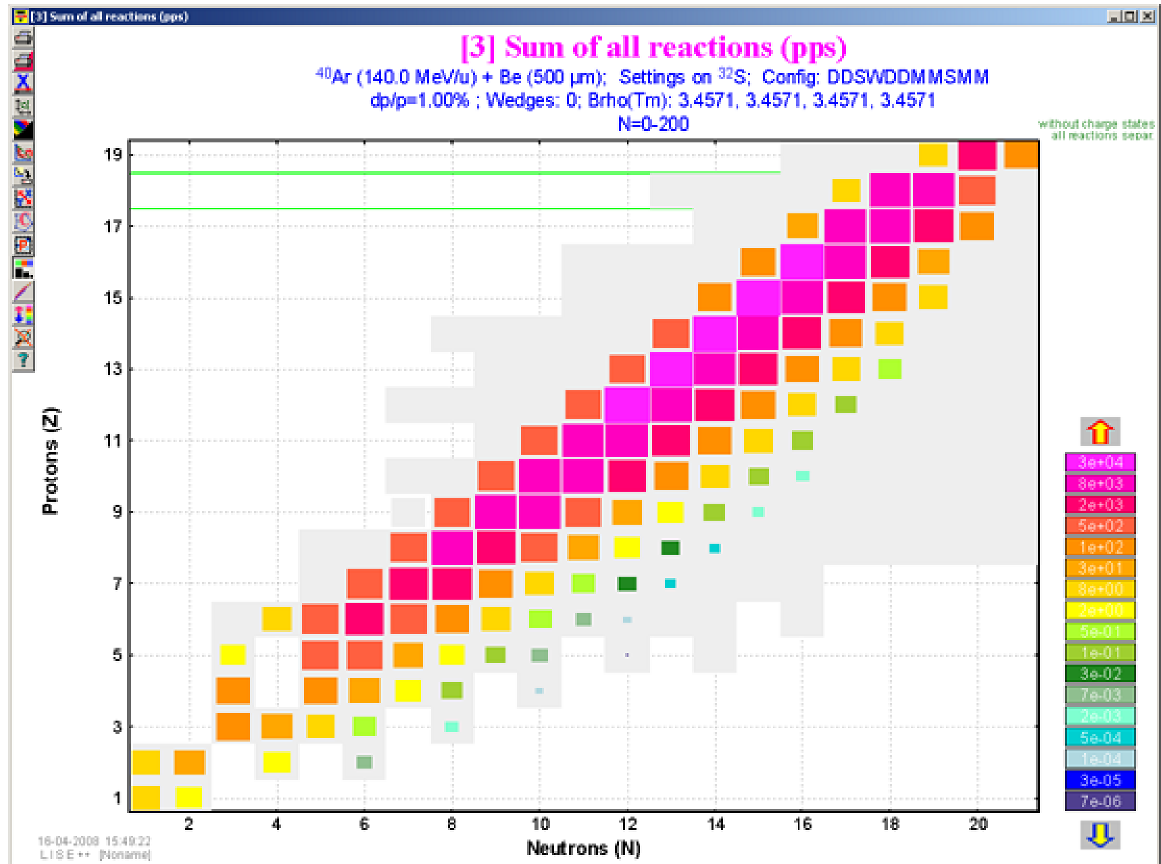
v.8.3.3. Plot dialog: button "NZ chart"





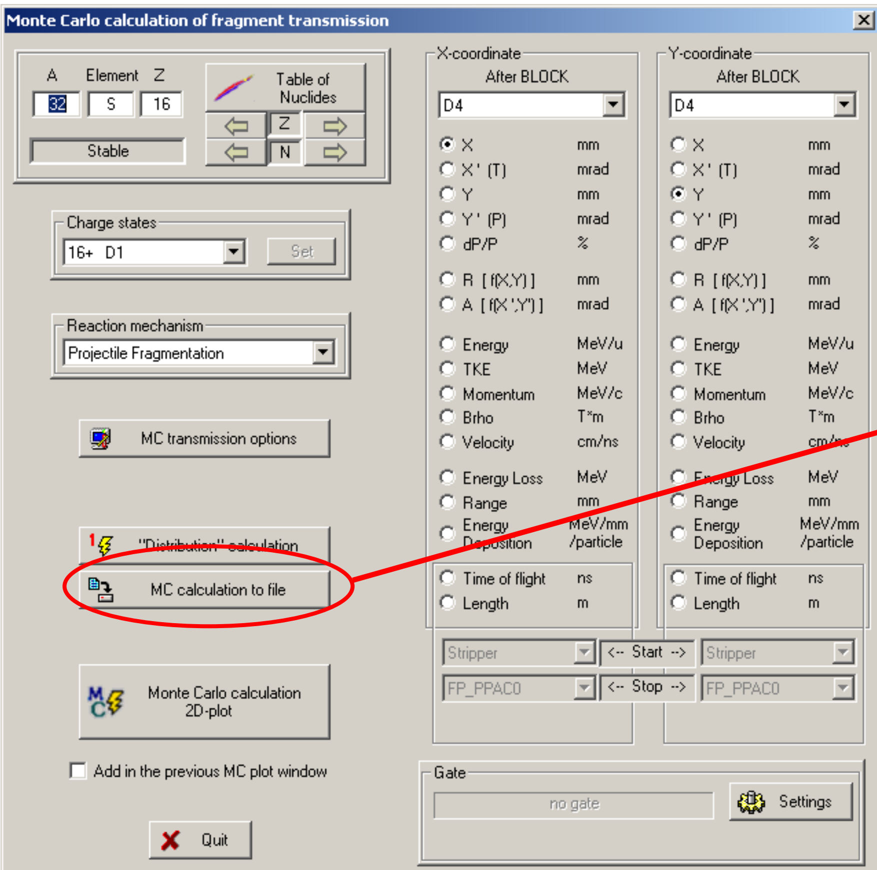
Set the next parameters:

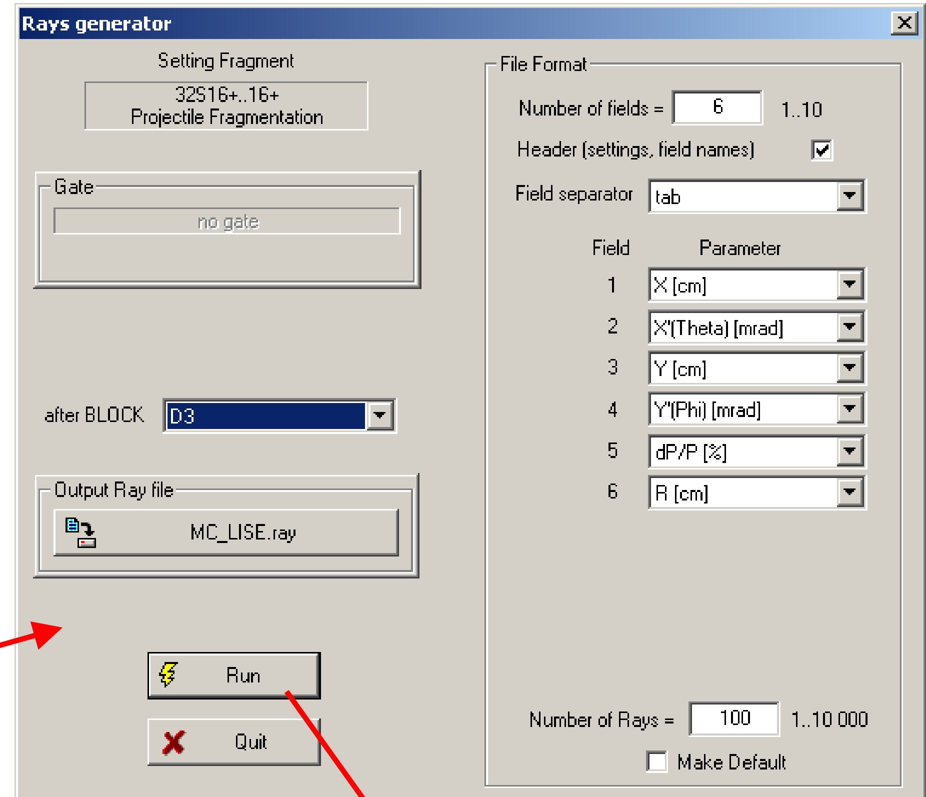
"2D", X="N", Y="Z", "N"=0-200

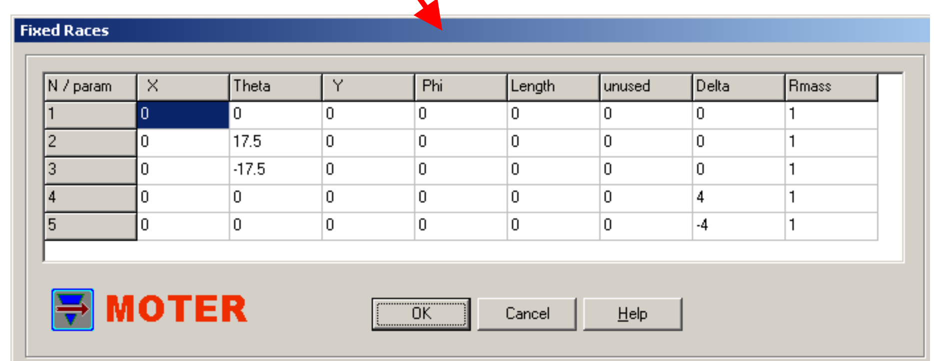


v. 8.3.2. Rays generator @ Monte Carlo dialog

LISE++ MC output rays file can be used for other programs as COSY, MOCADI, MOTER







M.Portillo's request

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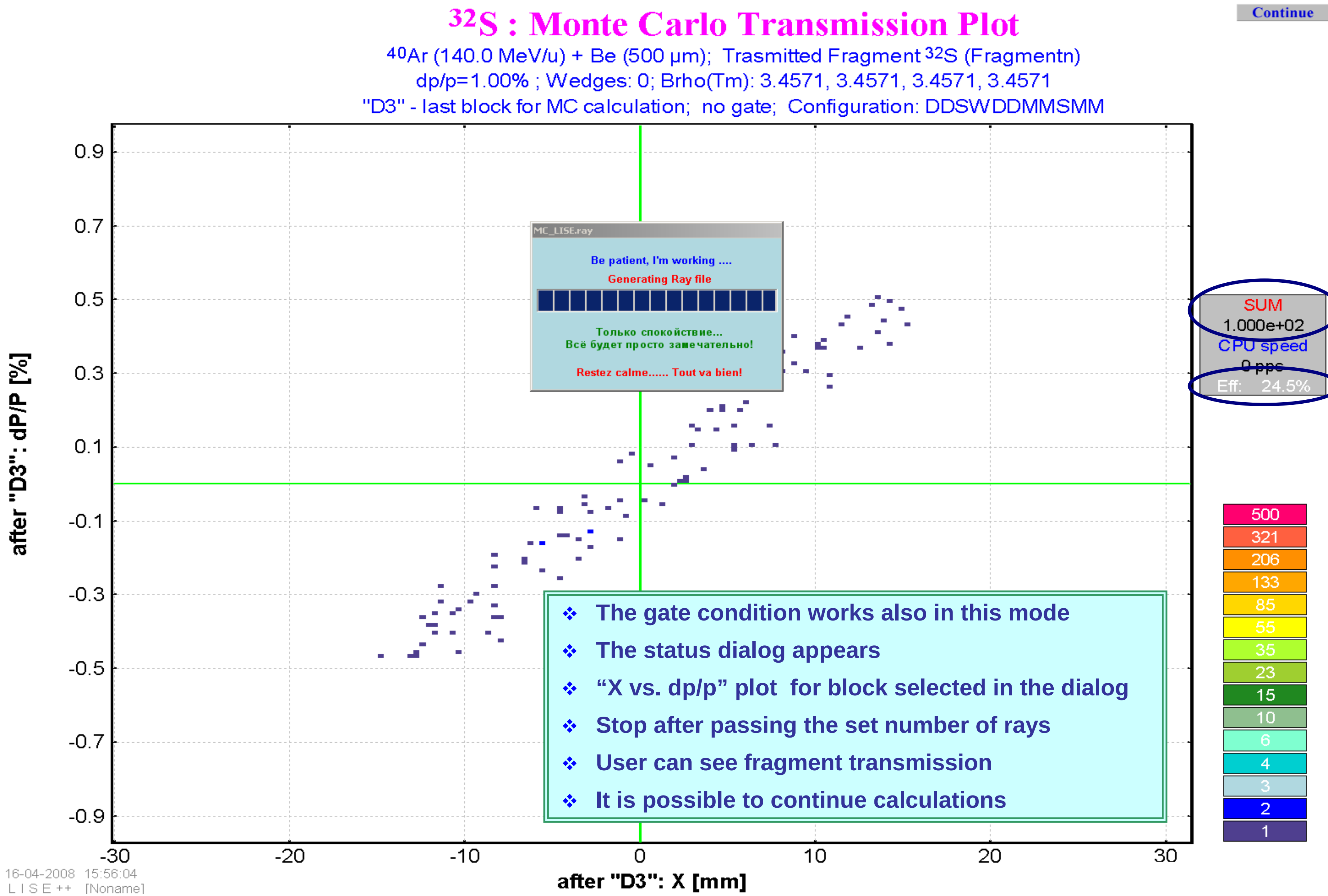
LISE++

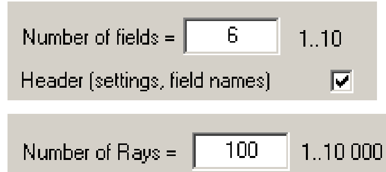


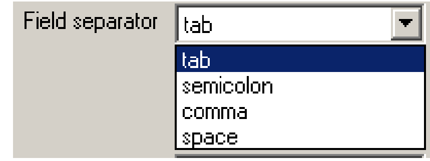
- The gate condition works also in this mode
- The status dialog appears
- “X vs. dp/p” plot for block selected in the dialog
- Stop after passing the set number of rays
- User can see fragment transmission
- It is possible to continue calculations

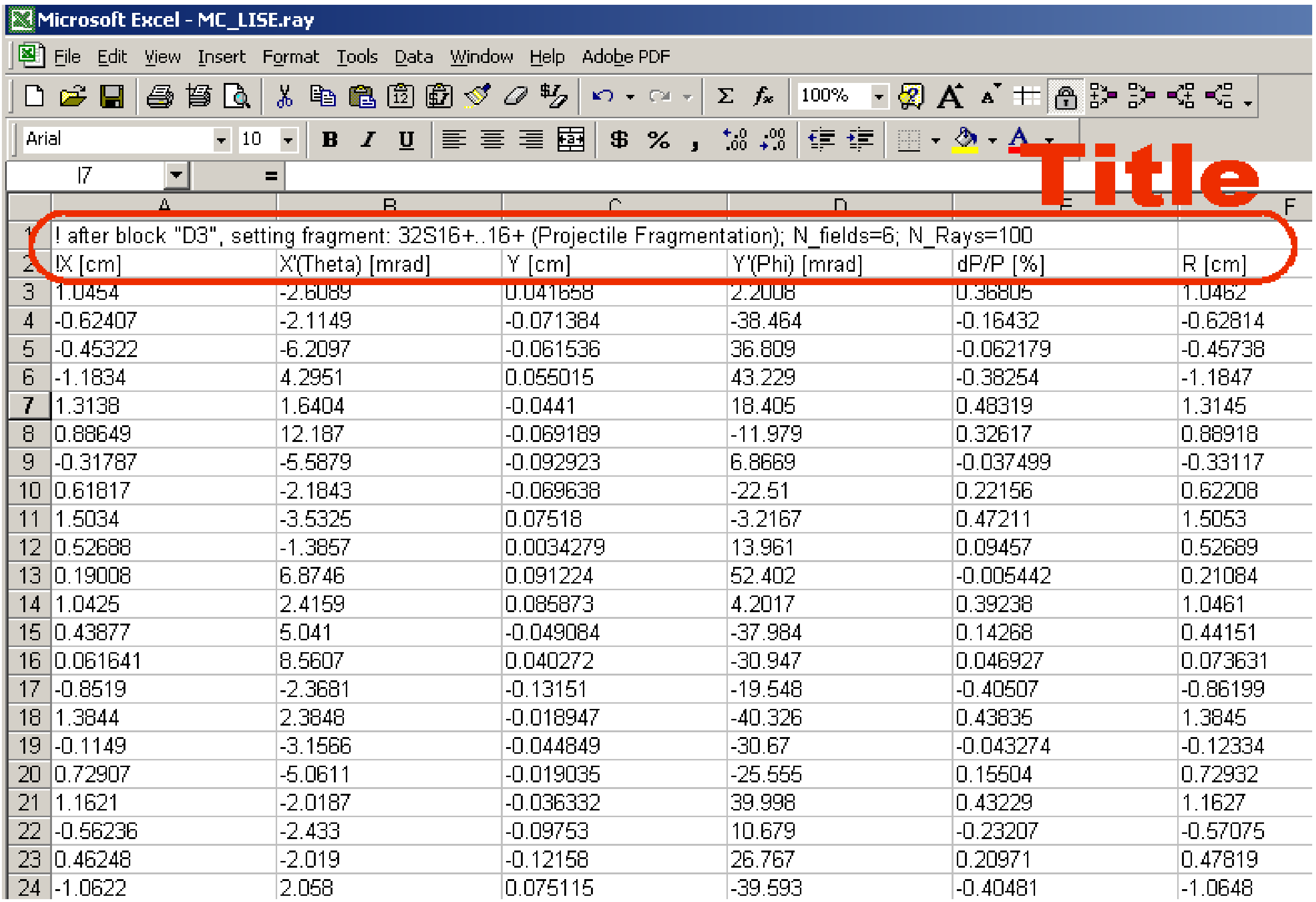
v. 8.3.2. Rays generator @ Monte Carlo dialog

Default : “ Lise / files ” directory

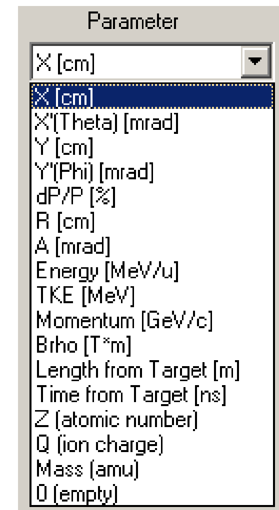
File Extension: “ *.ray ”



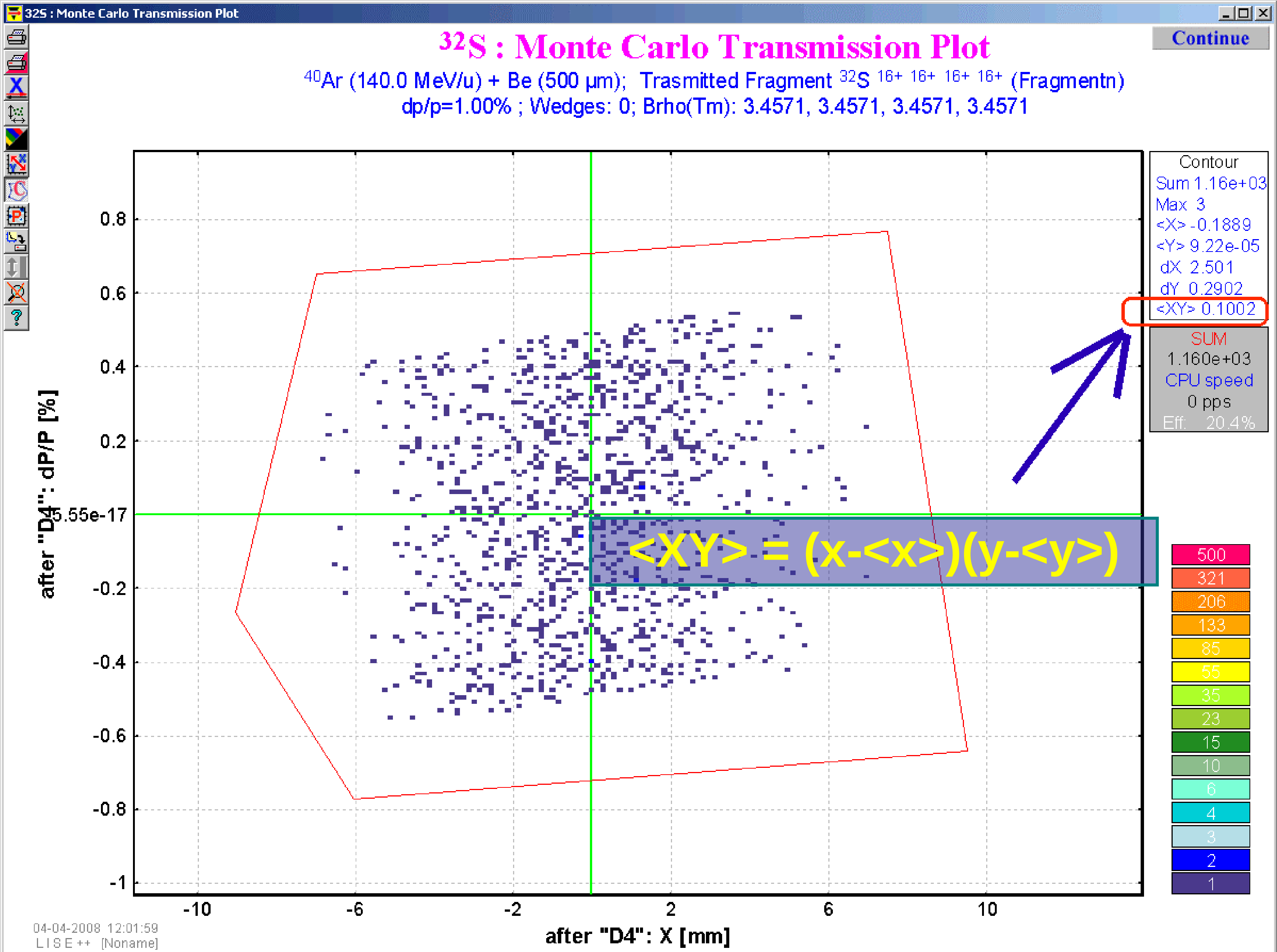




	A	B	C	D	E	F
1	! after block "D3", setting fragment: 32S16+..16+ (Projectile Fragmentation); N_fields=6; N_Rays=100					
2	!X [cm]	X'(Theta) [mrad]	Y [cm]	Y'(Phi) [mrad]	dP/P [%]	R [cm]
3	1.0454	-2.6089	0.041658	2.2008	0.36805	1.0462
4	-0.62407	-2.1149	-0.071384	-38.464	-0.16432	-0.62814
5	-0.45322	-6.2097	-0.061536	36.809	-0.062179	-0.45738
6	-1.1834	4.2951	0.055015	43.229	-0.38254	-1.1847
7	1.3138	1.6404	-0.0441	18.405	0.48319	1.3145
8	0.88649	12.187	-0.069189	-11.979	0.32617	0.88918
9	-0.31787	-5.5879	-0.092923	6.8669	-0.037499	-0.33117
10	0.61817	-2.1843	-0.069638	-22.51	0.22156	0.62208
11	1.5034	-3.5325	0.07518	-3.2167	0.47211	1.5053
12	0.52688	-1.3857	0.0034279	13.961	0.09457	0.52689
13	0.19008	6.8746	0.091224	52.402	-0.005442	0.21084
14	1.0425	2.4159	0.085873	4.2017	0.39238	1.0461
15	0.43877	5.041	-0.049084	-37.984	0.14268	0.44151
16	0.061641	8.5607	0.040272	-30.947	0.046927	0.073631
17	-0.8519	-2.3681	-0.13151	-19.548	-0.40507	-0.86199
18	1.3844	2.3848	-0.018947	-40.326	0.43835	1.3845
19	-0.1149	-3.1566	-0.044849	-30.67	-0.043274	-0.12334
20	0.72907	-5.0611	-0.019035	-25.555	0.15504	0.72932
21	1.1621	-2.0187	-0.036332	39.998	0.43229	1.1627
22	-0.56236	-2.433	-0.09753	10.679	-0.23207	-0.57075
23	0.46248	-2.019	-0.12158	26.767	0.20971	0.47819
24	-1.0622	2.058	0.075115	-39.593	-0.40481	-1.0648



v. 8.3.1. 2D plot Contour : new calculated value <XY>



M.Portillo's request

LISE^{++} development steps in the near future

- Densities in LISE.xls (D.Morrissey)
- Stripper foil lifetime utility : keeping parameters in LISE^{++} foil file (*.foil)
- Finish analysis with the Stripper foil lifetime utility

Comparison with experimental data

^{112}Sn @ MSU

^{238}U @ MSU

H^{-} @ BNL

H^{-} @ SNS

Analysis of some parameters

Current, Interaction area
Foil thickness
Beam energy
Emissivity factor
Heat capacity
Alpha
k1, k2
rotation target frequency

- Q3D configuration file (S.Lukyanov)
- Solenoid block (D.Morrissey)
- LISE^{++} site

FSEM08 presentation
Stripper foil lifietime utility
MOTER