

## Stripper Lifetime

(version 8.3.6)

- ❖ Introduction
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- ❖ Dialog
  - Beam settings
  - Shape
  - 2D-Gaussian dialog
  - Material properties
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  - Sublimation [2]
  - Radiation damages
- ❖ Pulsing beam
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- ❖ Comparison with experimental data
  - <sup>40</sup>Ar @ Dubna : Radiation damages
  - <sup>20</sup>Ne @ Dubna : Radiation damages
  - <sup>112</sup>Sn @ MSU : Radiation damages
  - <sup>238</sup>U @ MSU : ?
  - H<sup>-</sup> @ BNL [1] : *sublimation*

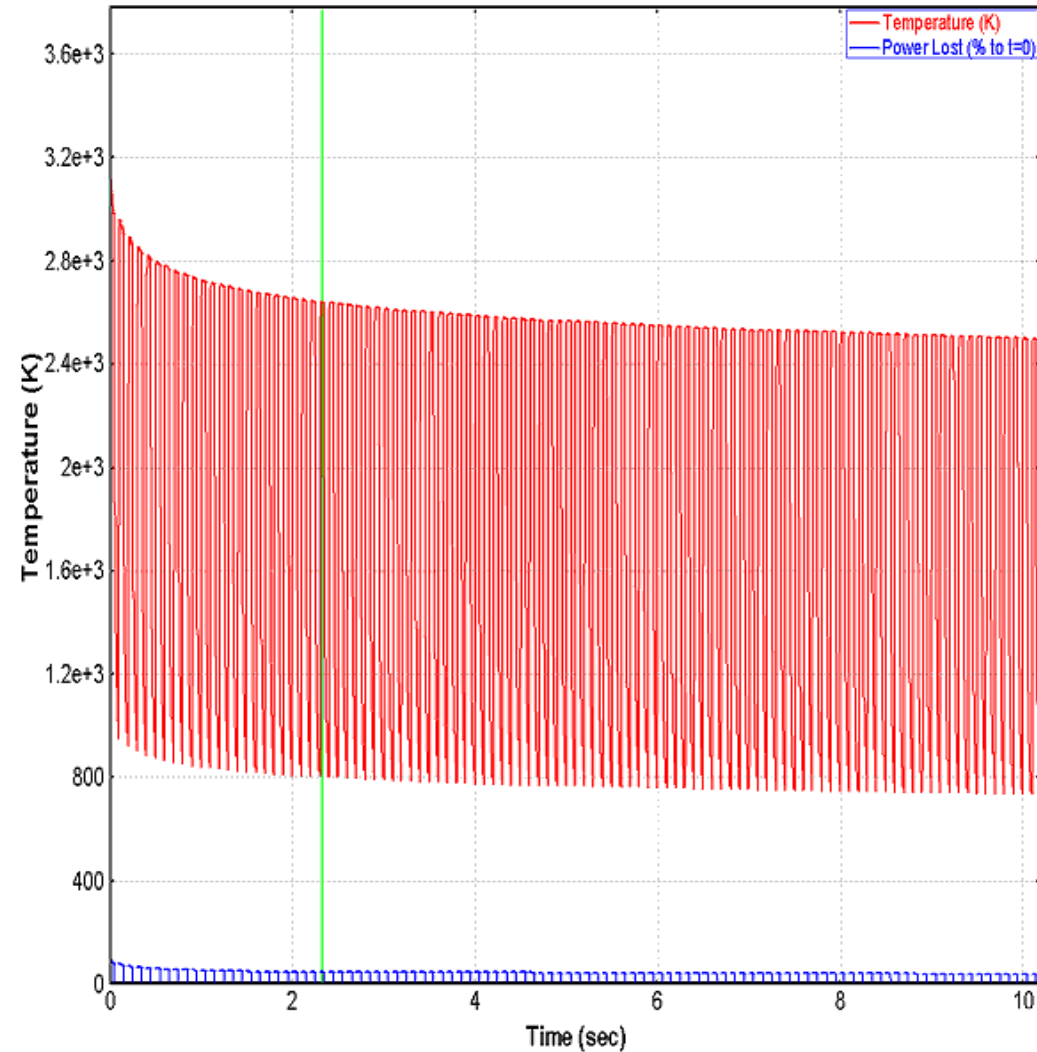
## Versions 8.3.1 – 8.3.4

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

## Influence of sublimation (Pulsing beam [1]): Temperature

<sup>238</sup>U Projectile Energy: 7.68 MeV/u Foil: C (0.4 mg/cm<sup>2</sup>)

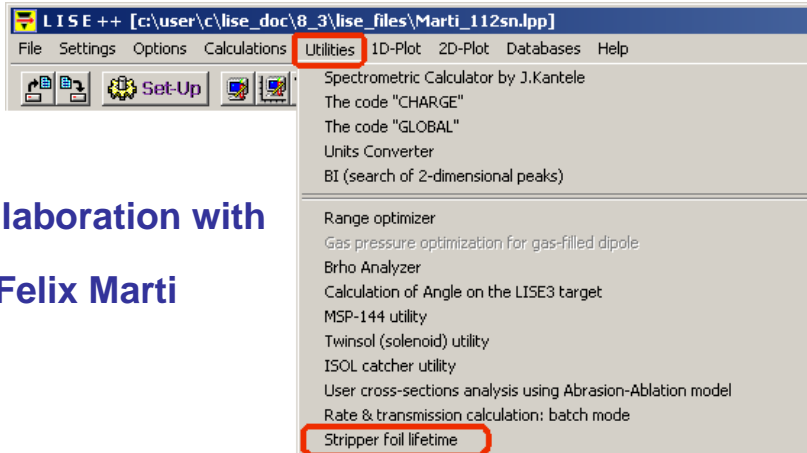
Left plot : Pulsing beam On-off Ratio = 50.00% Pulse length = 0.05 sec; Repetition rate = 10 sec<sup>-1</sup>  
 Beam current = 1.6e+04 W/cm<sup>2</sup> or 8.5 pA/cm<sup>2</sup>; epsilon=0.40; Lifetime = 2.32 sec



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.nsl.msu.edu/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

**Calculation of the lifetimes of thin stripper targets**

**Set-up**  
Beam: 112Sn Energy: 10.9 MeV/u Intensity: 2000 enA  
Foil: 12C Thickness: 0.5 mg/cm2

**Beam options**  
 Stationary beam  
 Pulsing beam  
 Stationary beam & rotating target

**Pulse structure**  
Beam pulse length: 0.00318 sec  
Rotation Frequency: 1 Hz  
Radial position of beam spot: 10 cm

**Shape**  
 2-D Gaussian length "L": 1 mm  
 Uniform: ellipse width "w": 1 mm  
 Uniform: rectangle Area: 1 mm2

**Material properties**  
epsilon (emissivity factor) = 0.8  
target's atom displacement energy = 25 eV  
 $time = k_1 \cdot K_d^{-5/4} \exp(-k_2/T)$   
k1 = 50 default 50 (Carbon)  
k2 = 870 default 870 (Carbon)

**Heat Capacity [J / g / K]**  
 Carbon capacity dependence [3] from T  
 manually (constant from T)  
c = 0.502

**Sublimation influence ("Pulsing beam" case [1])**  
alpha (eq.22 for [1]) = 8.12e+10 g K^(1/2) / sec/cm2  
Mode to plot (dimension):  
 F (N = 1e3)  S1 (N = 1e5) \*  
 M (N = 1e4)  S2 (N = 1e6) \*  
 \* - with compression  S3 (N = 1e7) \*  
Rise Time (dT=+100K) = 1.14e-04 sec [a]  
"Plateau" (dT= -1K) = 1.96e-03 sec [b]  
Fall Time (dT=-100K) = 3.20e-04 sec [c]  
Range to plot = 1.80e+01 sec  
Height & Temperature from Time  
[a] T0=293K  
[b] T0=Target warming up temperature, P>0  
[c] T0 as [b], but P=0

**Radiation damages**  
Kd (atom displacement rate) = 1.05e-03 1 / cm2  
Target warming up temperature = 2445.2 K [c]  
Foil lifetime due to radiation damages = 5.79e+07 sec / 1.6e+04 hour  
Lifetime and Temperature from Beam Current

**Sublimation influence ("Stationary beam" case [2])**  
alpha (eq.13 for [2]) = 7.83e+10 cm K^(1/2) / sec  
"Stationary beam" Foil lifetime due to sublimation = 2.12e+06 sec / 5.9e+02 hour  
Height (time) & Lifetime (Beam Current)

**Calculated beam characteristics**  
Beam power lost at the center of target (t=0) = 324 W / cm2  
Beam on-off time ratio = 0.3183 %  
Density of particle flux (at the center) = 11.8 puA / cm2 / 7.35e+13 pps / cm2

**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

## 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.nsci.msu.edu/lise/paper/foil/>

## Index of /lise/paper/foil

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<a href="#">Gikal JINR P9-2005-110 english.pdf</a>	29-Mar-2008 13:01	239K	
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<a href="#">Liaw PAC99 Carbon Foil Temperature.pdf</a>	10-Apr-2008 11:40	39K	

Translated by O.B.Tarasov  
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 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  $\mu\text{g}/\text{cm}^2$  thick and for the ion beam flux density up to 100  $\mu\text{A}/\text{cm}^2$  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<sup>1</sup> and A. S. Lebedev<sup>2</sup>

<sup>1</sup>Institute for Nuclear Research of the Russian Academy of Sciences, 60th October Anniversary Prospect, 7a, Moscow, 117312, Russia  
<sup>2</sup>Lomonosov Moscow State University, Faculty of Calculus Mathematics and Cybernetics, Vorobievsky 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](https://doi.org/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  $\mu\text{g}/\text{cm}^2$  and 400  $\mu\text{g}/\text{cm}^2$  carbon foils, used to strip the 1 GeV H<sup>+</sup> 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

$\mu\text{g}/\text{cm}^2$  foils. A 225  $\mu\text{g}/\text{cm}^2$  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.

**Beam**

A	Element	q+
112	Sn	17
Z		
Stable		

Table of Nuclides

Beam energy

Energy	10.86	MeV/u
TKE	1215.29	MeV
Brho	3.1323	Tm
P	15.964	GeV/c
U	7.15e+4	KV

Beam intensity

<input checked="" type="radio"/>	2000	enA
<input type="radio"/>	117.6	pnA
<input type="radio"/>	7.3529e+11	pps
<input type="radio"/>	0.1431	KW

Emittance

Beam CARD (sigma)

1. X	0.5	mm
2. T	6	mrاد
3. Y	0.5	mm
4. P	8	mrاد
5. L	0	mm
6. D	0.07	%

mm  cm

Energy Loss in the target box [KW]  **LISE++ fragment separator target**

beam shape parameters for all three modes (gaussian, ellipse, rectangle)

**Set-up**

Beam 112Sn Energy = 10.9 MeV/u

Foil 12C Intensity = 2000 enA

Thickness = 0.5 mg/cm2

**Target**

C Density 2.253 g/cm3

State  Solid  Gas

Dimension  mg/cm2 & micron  g/cm2 & mm

Angle  degrees

Z	Element	Mass
<input checked="" type="checkbox"/>	6 C PT	12.011
<input type="checkbox"/>	14 Si	28.086
<input type="checkbox"/>	14 Si	28.086
<input type="checkbox"/>	14 Si	28.086
<input type="checkbox"/>	14 Si	28.086

Compound dictionary

Thickness at 0 degrees  2.2192632 micron  0.5 mg/cm2

Effective Thickness  2.2192632 micron  0.5 mg/cm2

Atoms quantity / cm2 2.51e+19

OK Cancel

<p>Beam options</p> <p><input checked="" type="radio"/> Stationary beam</p> <p><input type="radio"/> Pulsing beam</p> <p><input type="radio"/> Stationary beam &amp; rotating target</p>	<p>Pulse structure</p>
--	------------------------



Beam on-off time ratio =  %

<p>Beam options</p> <p><input type="radio"/> Stationary beam</p> <p><input checked="" type="radio"/> Pulsing beam</p> <p><input type="radio"/> Stationary beam &amp; rotating target</p>	<p>Pulse structure</p> <p>Beam pulse length = <input type="text" value="0.01"/> sec</p> <p>Repetition rate = <input type="text" value="10"/> Hz</p>
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Rectangle shape of pulse



Beam on-off time ratio =  %

<p>Beam options</p> <p><input type="radio"/> Stationary beam</p> <p><input type="radio"/> Pulsing beam</p> <p><input checked="" type="radio"/> Stationary beam &amp; rotating target</p>	<p>Pulse structure</p> <p>Beam pulse length = <input type="text" value="0.00015"/> sec</p> <p>Rotation Frequency = <input type="text" value="10"/> Hz</p> <p>Radial position of beam spot = <input type="text" value="10"/> cm</p>
--	--



Beam on-off time ratio =  %

$$\tau = \frac{R_{reduced}}{\pi v R_{pos}}$$

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

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

Beam settings

Beam CARD (sigma)

1. X  mm

3. Y  mm

Calculation of flux distribution parameters

Interaction area =  cm<sup>2</sup>

Beam percent in this area =  % (should be between 5 and 99 %)

Reduced beam spot radius (sigma) =  mm

Apply the value in the Lifetime dialog  Quit

$$f(r) := \frac{1}{2 \cdot \pi \cdot \sigma^2} \cdot \exp\left(\frac{-r^2}{2 \cdot \sigma^2}\right)$$

$$\int_0^{\infty} 2 \cdot \pi \cdot r \cdot f(r) \, dr = 1$$

$\sigma \equiv$  ReducedRadius

Shape

2-D Gaussian  Uniform: ellipse  Uniform: rectangle

Radius from Interaction Area

Reduced beam spot radius (sigma) =  mm

Area (90%) =  mm<sup>2</sup>

Calculated beam characteristics

Beam power lost at the center of target (t=0) =  W / cm<sup>2</sup>

Beam on-off time ratio =  %

Density of particle flux (at the center) =  pA / cm<sup>2</sup>

pps / cm<sup>2</sup>

Shape

2-D Gaussian  Uniform: ellipse  Uniform: rectangle

semior axis "a" =  mm

semior axis "b" =  mm

Area =  mm<sup>2</sup>

Calculated beam characteristics

Beam power lost at the center of target (t=0) =  W / cm<sup>2</sup>

Beam on-off time ratio =  %

Density of particle flux (at the center) =  pA / cm<sup>2</sup>

pps / cm<sup>2</sup>

Shape

2-D Gaussian  Uniform: ellipse  Uniform: rectangle

length "L" =  mm

width "w" =  mm

Area =  mm<sup>2</sup>

Calculated beam characteristics

Beam power lost at the center of target (t=0) =  W / cm<sup>2</sup>

Beam on-off time ratio =  %

Density of particle flux (at the center) =  pA / cm<sup>2</sup>

pps / cm<sup>2</sup>

Material properties

epsilon (emissivity factor) =  0.. 1

target's atom displacement energy =  eV

$time = k_1 \cdot K_d^{-5/4} \exp(-k_2/T)$

k1 =  default 50 (Carbon)

k2 =  default 870 (Carbon)

---

Heat Capacity [J / g / K]

Carbon capacity dependence [3] from T

manually (constant from T)

c =

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

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

[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

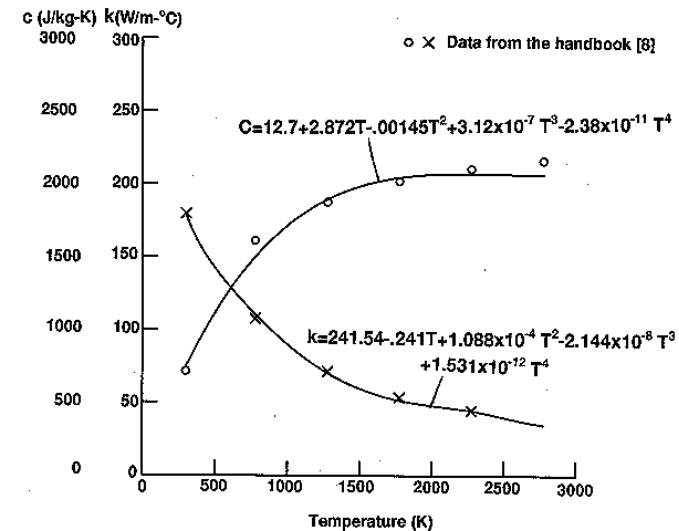
### Heat capacity

**Heat capacity** (symbol:  $C_p$ )—as distinct from **specific heat capacity**—is the measure of the heat energy required to raise the temperature of an object; for example, a bathtub of water has a greater heat capacity than a cup of water. 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 limit 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 renders this detail moot. An exception would be when an object has an accurately known heat capacity. An exception would be when the defined state varies significantly from standard conditions.

#### Table of specific heat capacities

Substance	Phase	$C_p$ J g <sup>-1</sup> K <sup>-1</sup>	$C_{p,m}$ J mol <sup>-1</sup> K <sup>-1</sup>	$C_v$ J mol <sup>-1</sup> K <sup>-1</sup>	Volumetric heat capacity J cm <sup>-3</sup> K <sup>-1</sup>
Air (Sea level, dry, 0 °C)	gas	1.0035	29.07	20.7643	
Air (typical room conditions <sup>a</sup> )	gas	1.012	29.19	20.85	
Aluminium	solid	0.897	24.2		2.422
Ammonia	liquid	4.700	<b>80.08</b>		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

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

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

$$\frac{dh(t)}{dt} = -8.12 \times 10^{10} \frac{\exp\left[\frac{-83500}{T}\right]}{\sqrt{T}}$$

Sublimation influence ("Pulsing beam" case [1])

alpha (eq.22 for [1]) =  g K^(1/2) /sec/cm2  
default 8.12e10 (Carbon)

Mode to plot (dimension)

F (N = 1e3)     S1 (N = 1e5) \*

M (N = 1e4)     S2 (N = 1e6) \*

\* - with compression     S3 (N = 1e7) \*

Rise Time (dT=+100K) =  sec [a]

"Plateau" (dT= -1K) =  sec [b]

Fall Time (dT=-100K) =  sec [c]

Range to plot =  sec

Height & Temperature from Time

[a] T0=293K  
[b] T0=Target warming up temperature, P>0  
[c] T0 as [b], but P=0

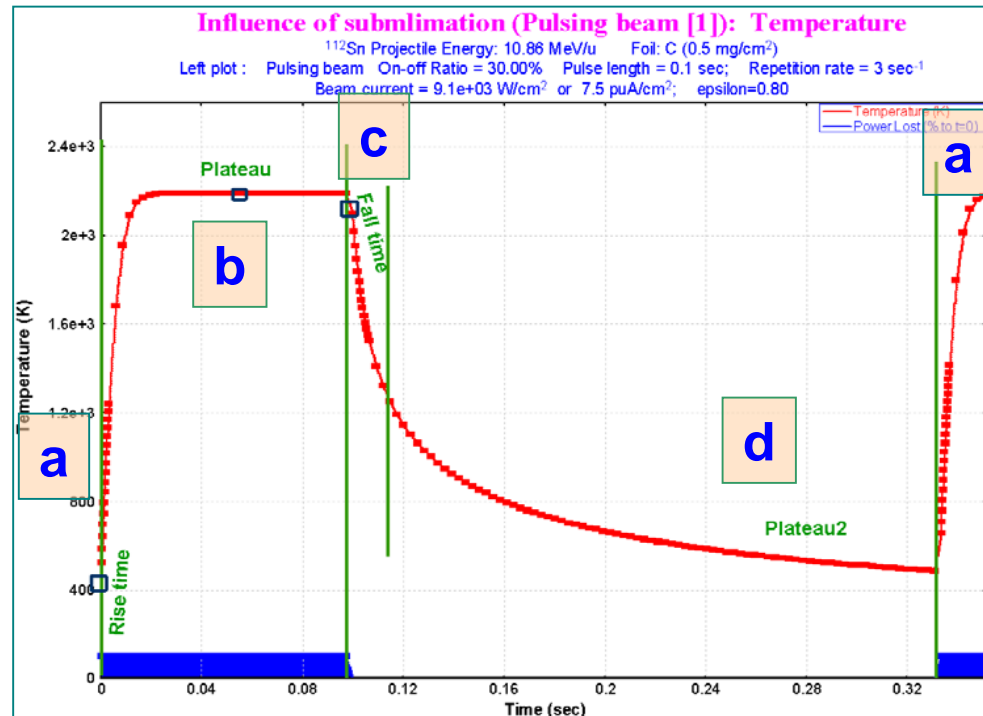
*N : LISE++ distribution dimension.  
How many points will be used for integration*

*S1 : only each 10<sup>th</sup> calculated point will be plotted  
S2 : only each 100<sup>th</sup> point  
S3 : only each 1000<sup>th</sup> point*

Target warming up temperature =  K [c]

*4 integration region with different steps in order to*

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





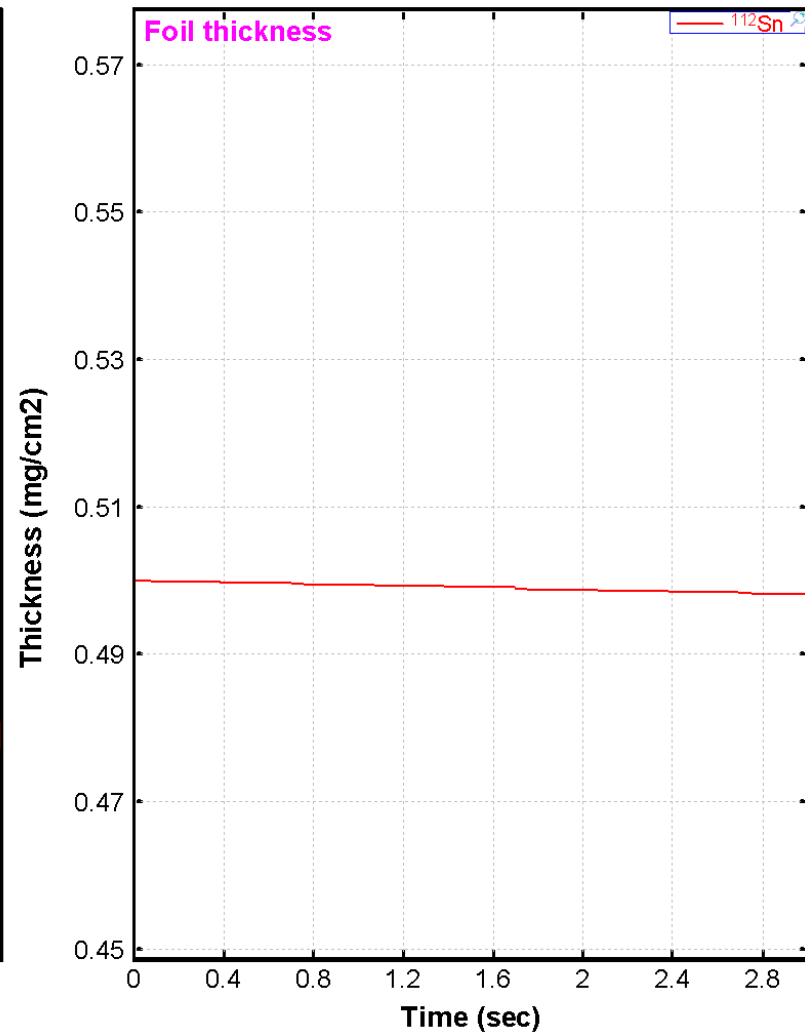
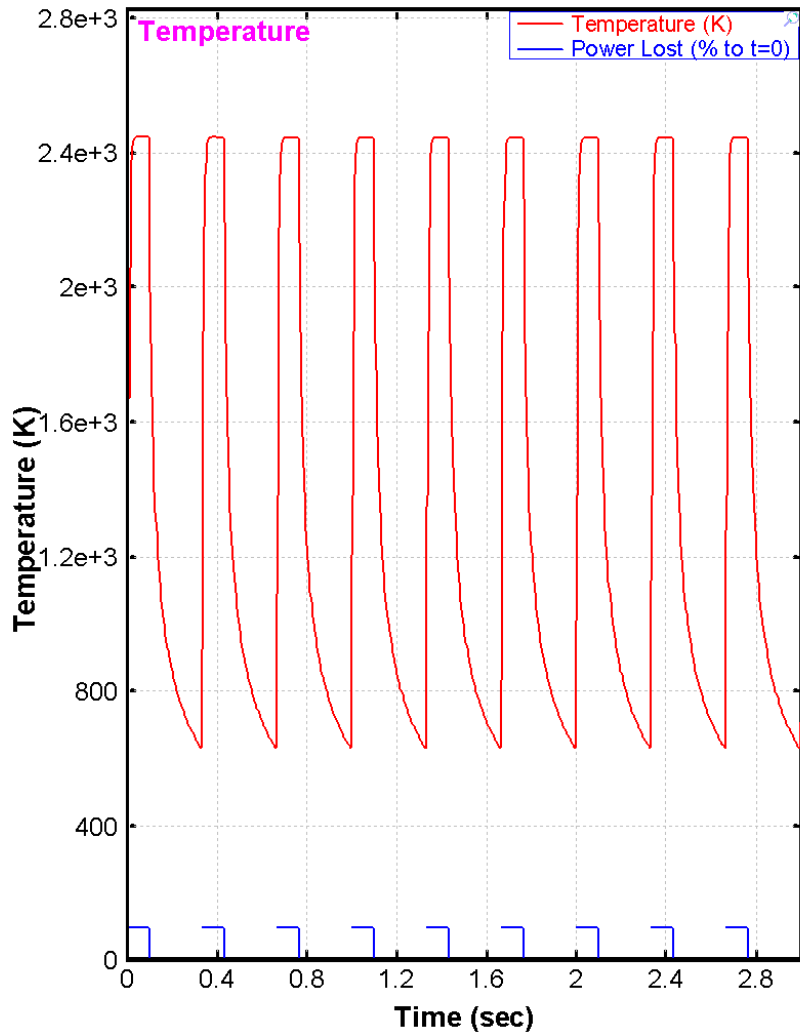
	Range to plot (sec)	
Mode	Stationary	Pulsing (30% on-off time ratio)
F	7.59E+00	3.00E+00
M	7.79E+01	2.87E+01
S1	7.82E+02	2.69E+02
S2	7.82E+03	2.69E+03
S3	7.82E+04	2.69E+04
Lifetime	6.80E+03	~ 3E+04

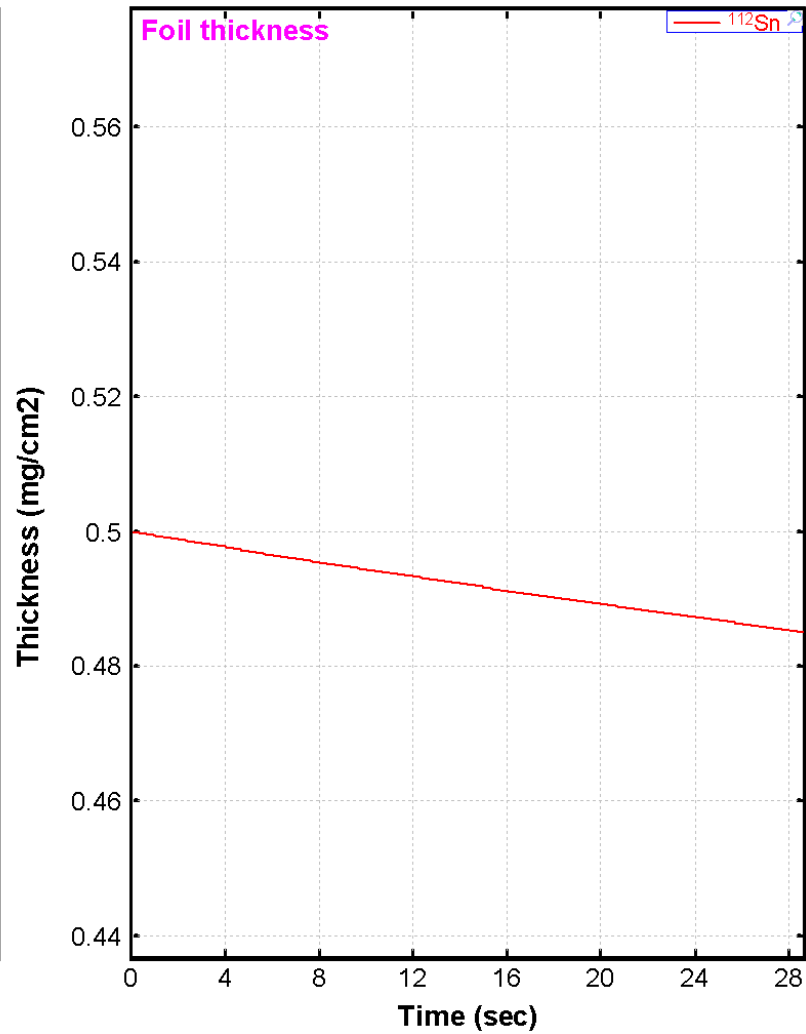
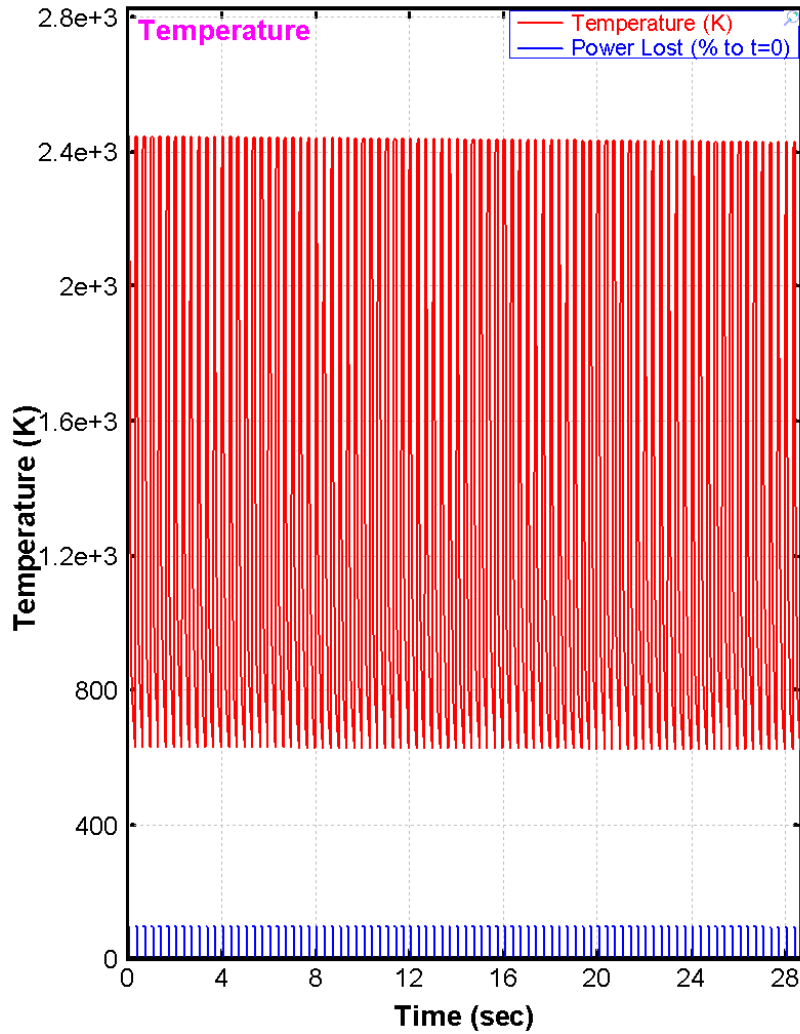
## Settings

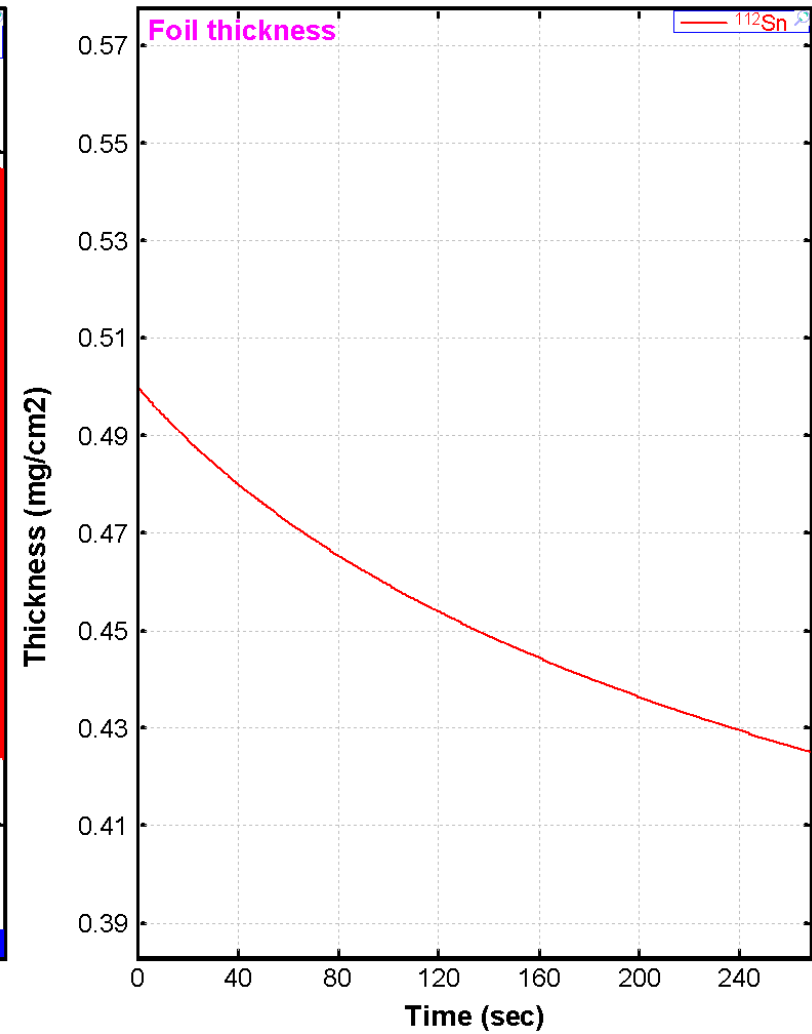
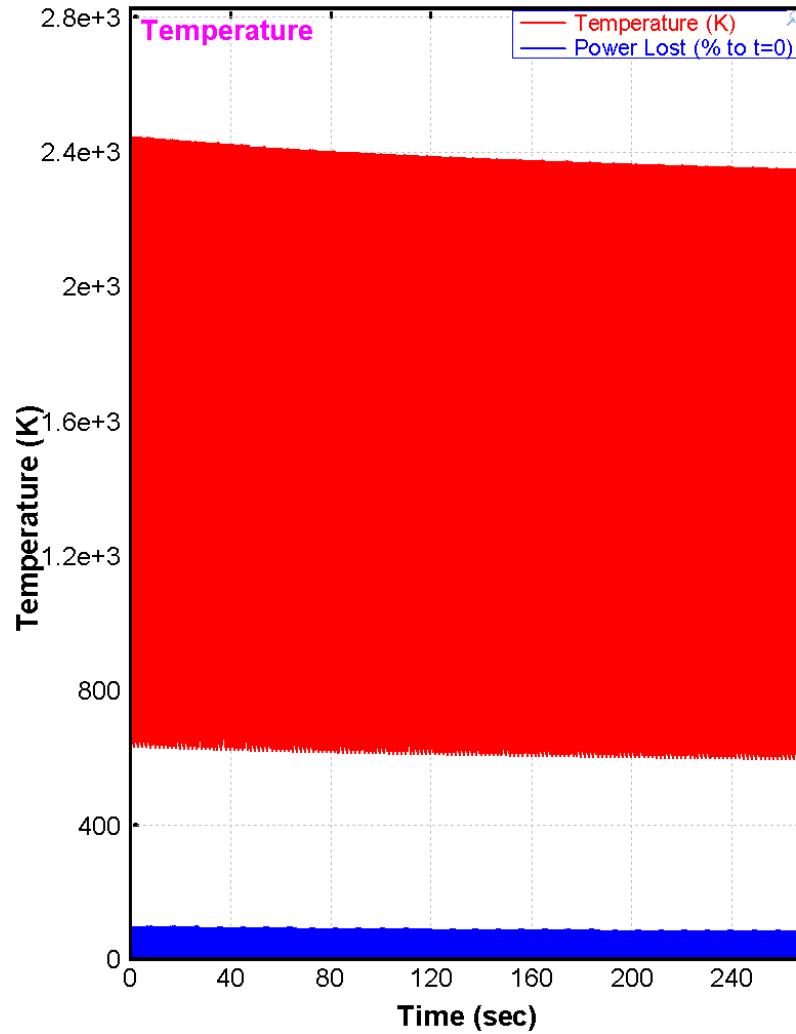
## Influence of sublimation (Pulsing beam [1])

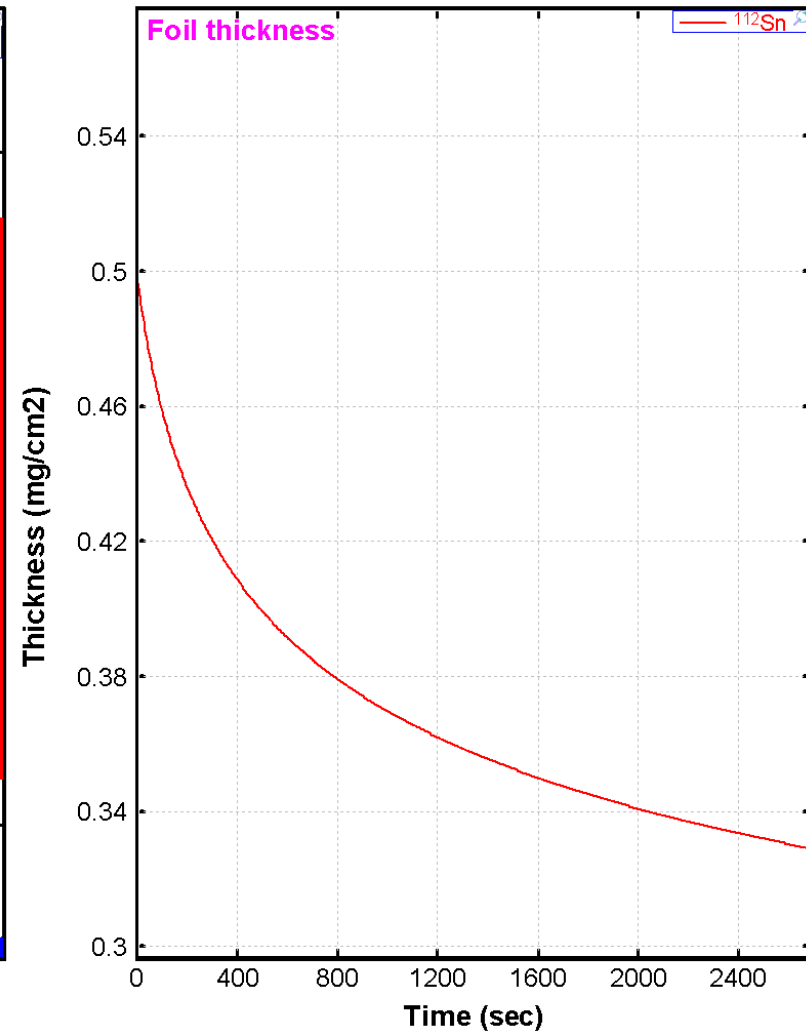
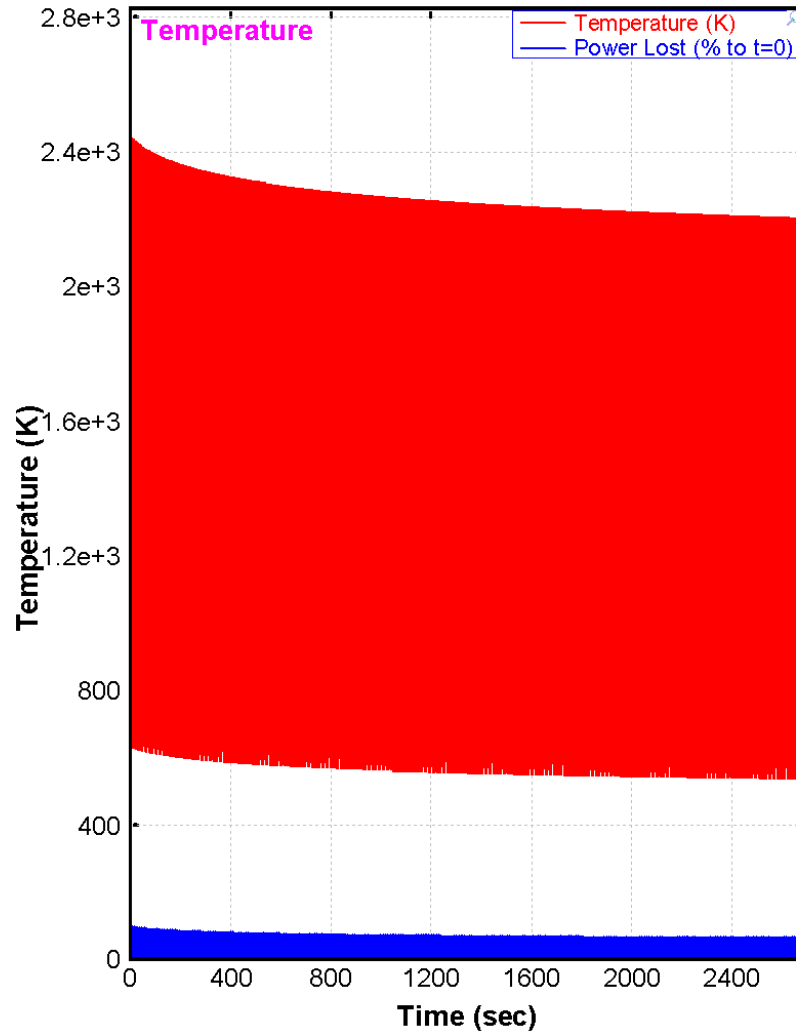
<sup>112</sup>Sn Projectile Energy: 10.86 MeV/u Foil: C (0.5 mg/cm<sup>2</sup>)

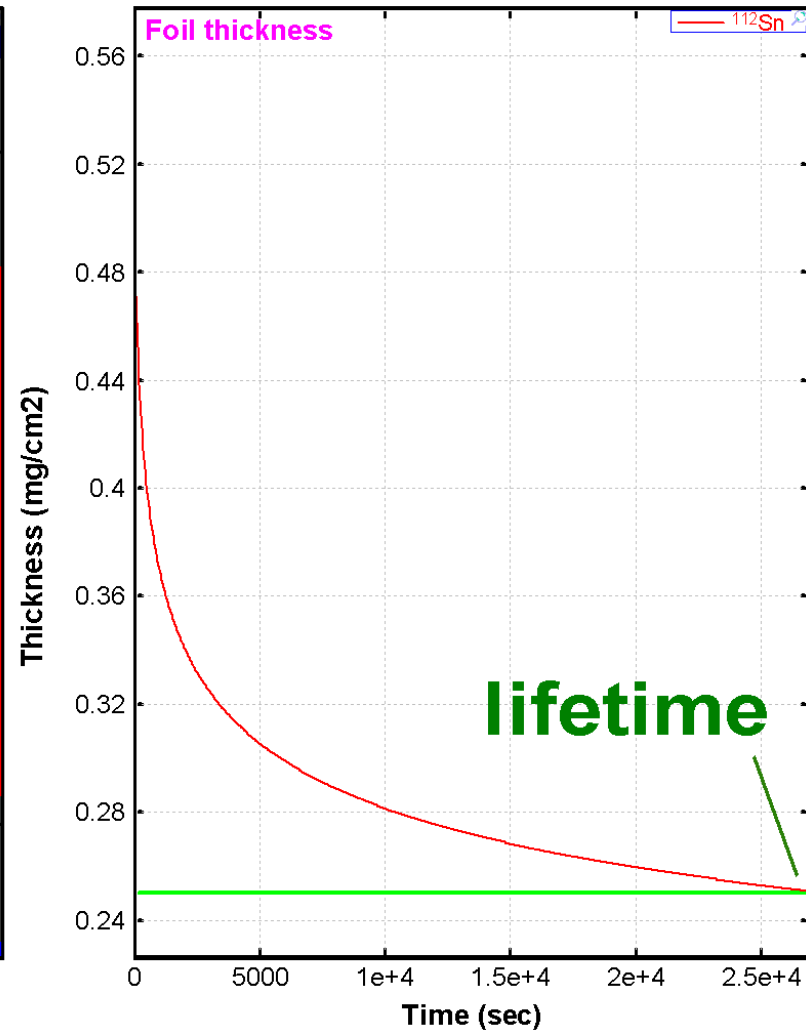
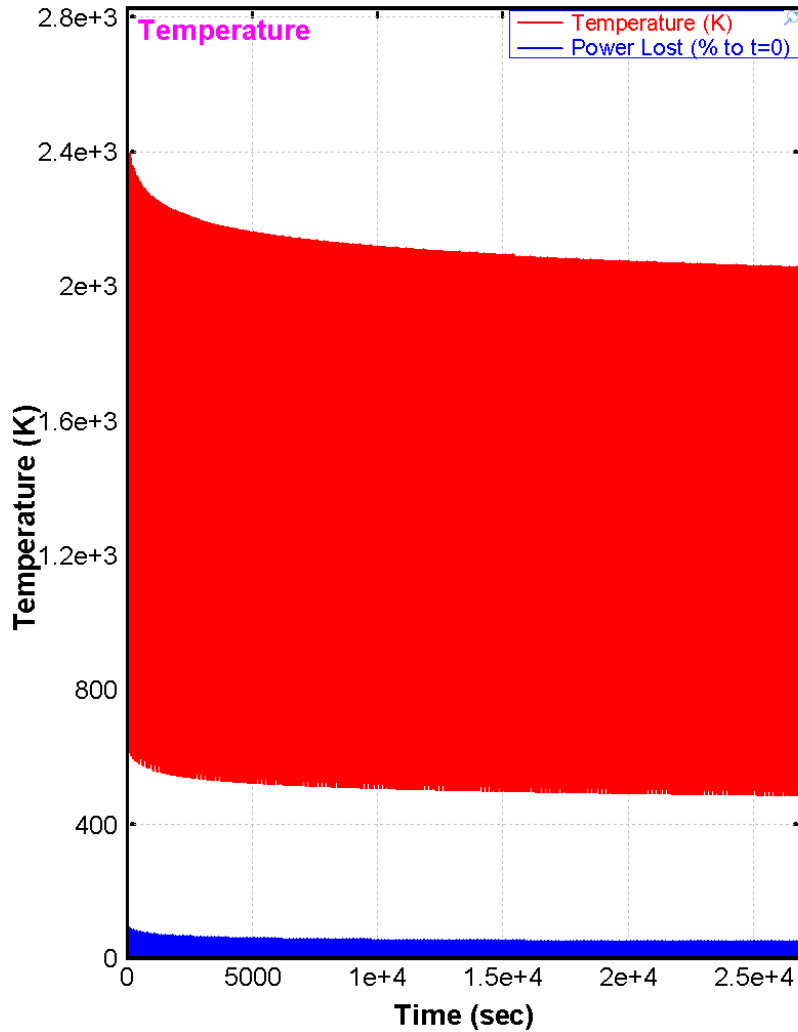
Left plot: Pulsing beam On-off Ratio = 30.00% Pulse length = 0.1 sec; Repetition rate = 3 sec<sup>-1</sup>  
Beam current = 7.2e+03 W/cm<sup>2</sup> or 5.9 pA/cm<sup>2</sup>; epsilon=0.40

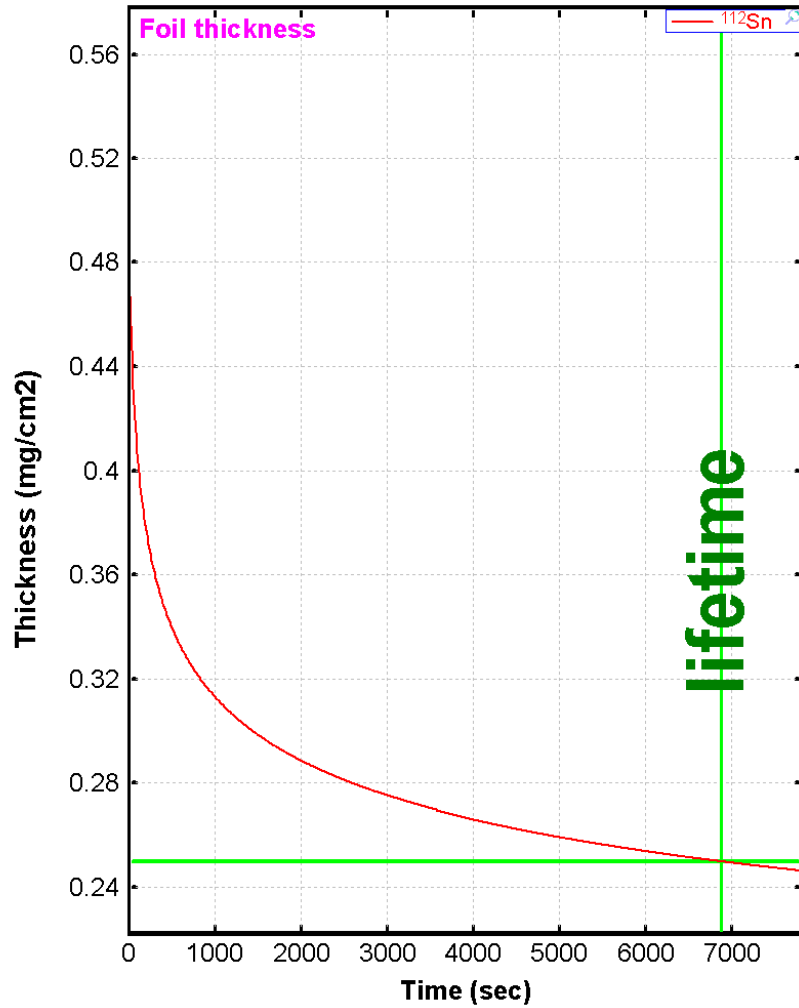
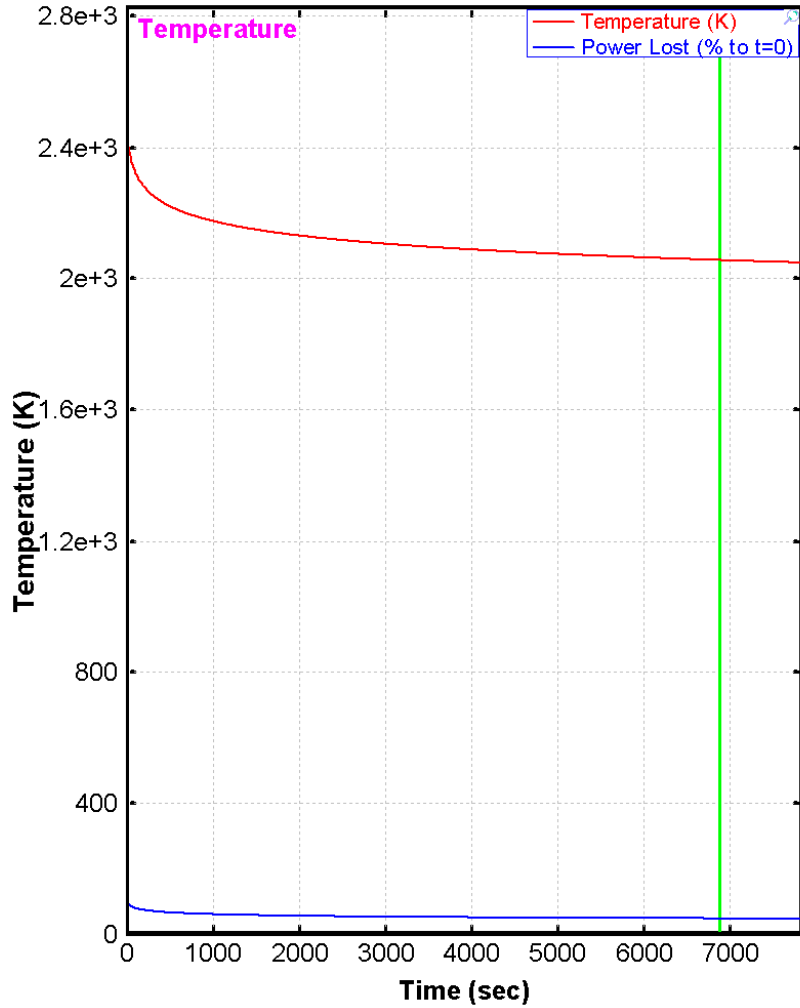












Sublimation influence ("Stationary beam" case [2])

alpha (eq.13 for [2]) =  cm K<sup>1/2</sup> / sec  
 default 7.83e10 (Carbon)

"Stationary beam"  
 Foil lifetime due to sublimation =  sec  
 hour

Height (time) & Lifetime (Beam Current)

Integration by Euler's method  
 with exponential step

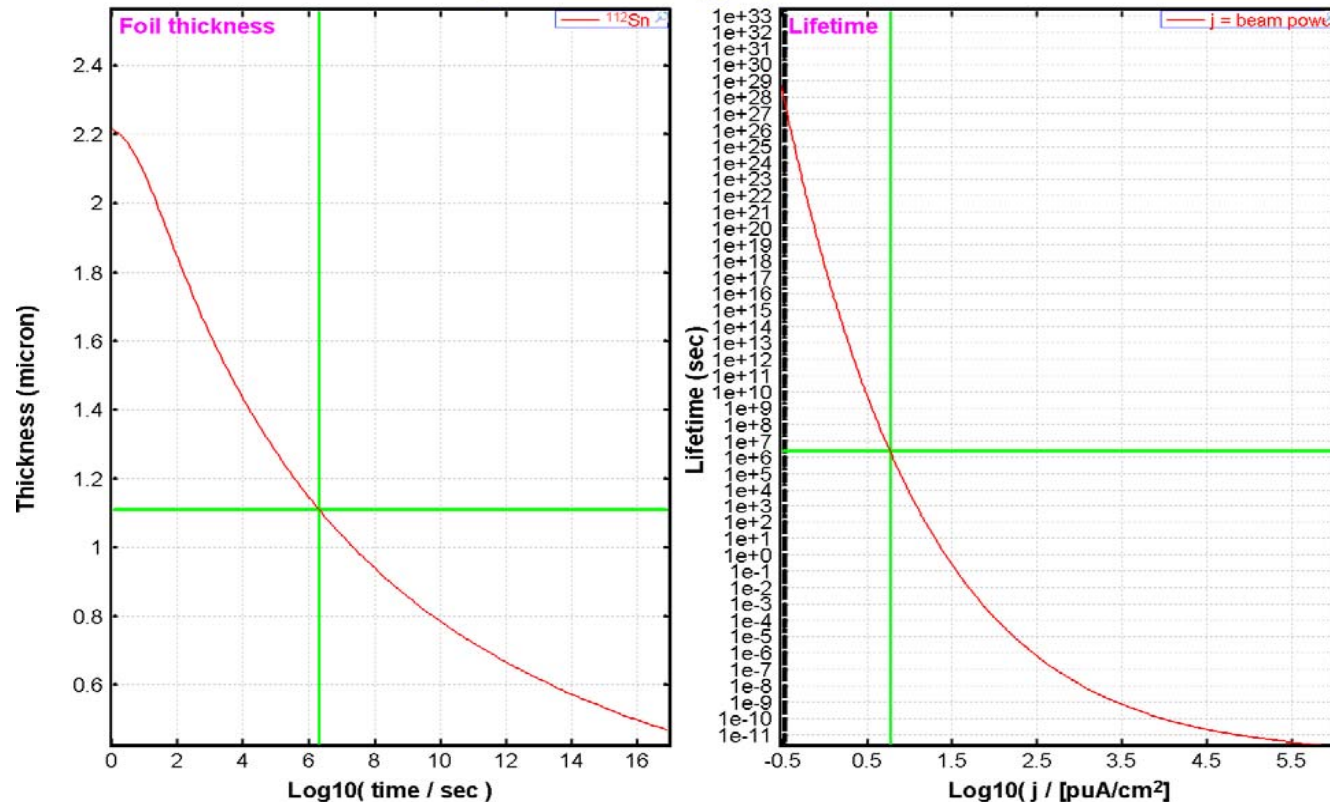
$$\frac{dh(t)}{dt} = -\alpha \cdot \frac{\exp\left(\frac{-B}{\beta \sqrt[4]{h(t)}}\right)}{\sqrt{\beta} \cdot \sqrt[4]{h(t)}}$$

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

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

## Influence of sublimation (Stationary beam [2])

Projectile Energy: 10.86 MeV/u    Foil: C (0.5 mg/cm<sup>2</sup>)  
 Left plot : power lost = 1.6e+02 W/cm<sup>2</sup> corresponds to current = 7.2e+03 W/cm<sup>2</sup> or 5.9 puA/cm<sup>2</sup>  
 epsilon=0.40    Method [2] : alpha=7.8e+10 cm K<sup>1/2</sup> sec<sup>-1</sup>





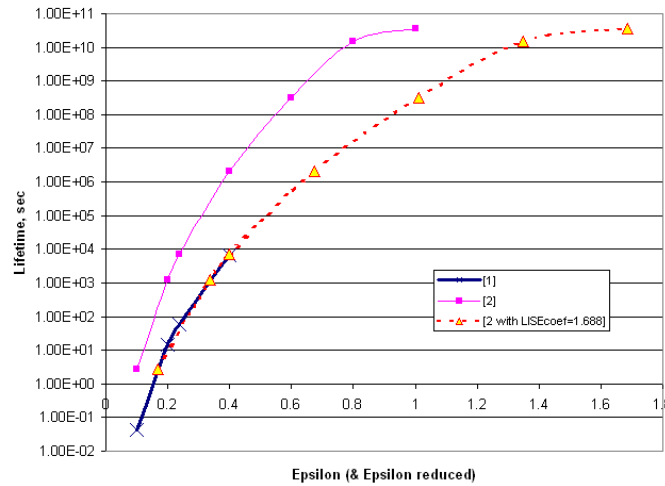
Sublimation influence ("Stationary beam" case [2])

alpha (eq.13 for [2]) =  cm K^(1/2) / sec  
 default 7.83e10 (C)

**LISEcoef =  0.1 ... 10 (deflt 1.7)**

"Stationary beam" Foil lifetime due to sublimation =  sec  
 hour

Height (time) & Lifetime (Beam Current)

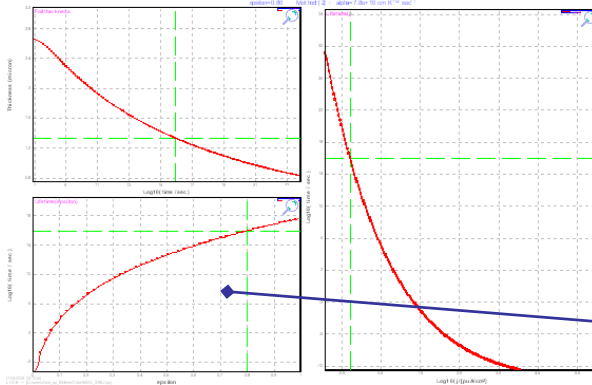


For agreement with [1]

$$\beta = 4 \sqrt{\frac{P \cdot LISEcoef}{h_0 \cdot \epsilon \cdot \sigma_0 \cdot 2}}$$

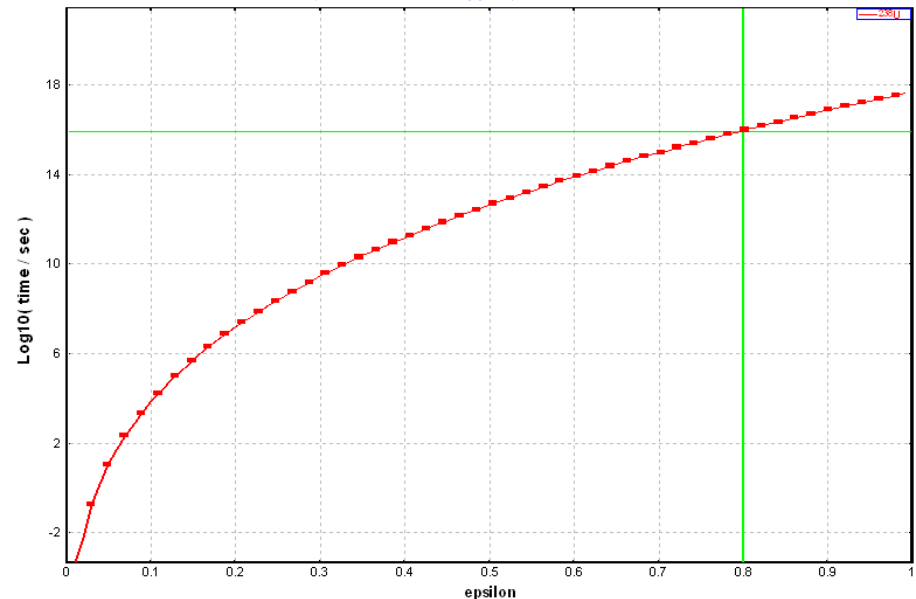
LISEcoef = 1.7

Influence of sublimation (Stationary beam [1])



Influence of sublimation (Stationary beam [2]): Lifetime(epsilon)

Projectile Energy: 7.68 MeV/u Foil: C (0.6 mg/cm<sup>2</sup>)  
 Left top plot: power lost = 41 W/cm<sup>2</sup> corresponds to current = 9.7e+02 W/cm<sup>2</sup> or 0.53 pA/cm<sup>2</sup>  
 epsilon=0.80 Method [2]: alpha=7.8e+10 cm K<sup>1/2</sup> sec<sup>-1</sup>



Radiation damages

Kd (atom displacement rate) =  1 / cm2

Target warming up temperature =  K [c]

Foil lifetime due to radiation damages =  sec

hour

Lifetime and Temperature from Beam Current

[1]'s algorithm was used

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

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

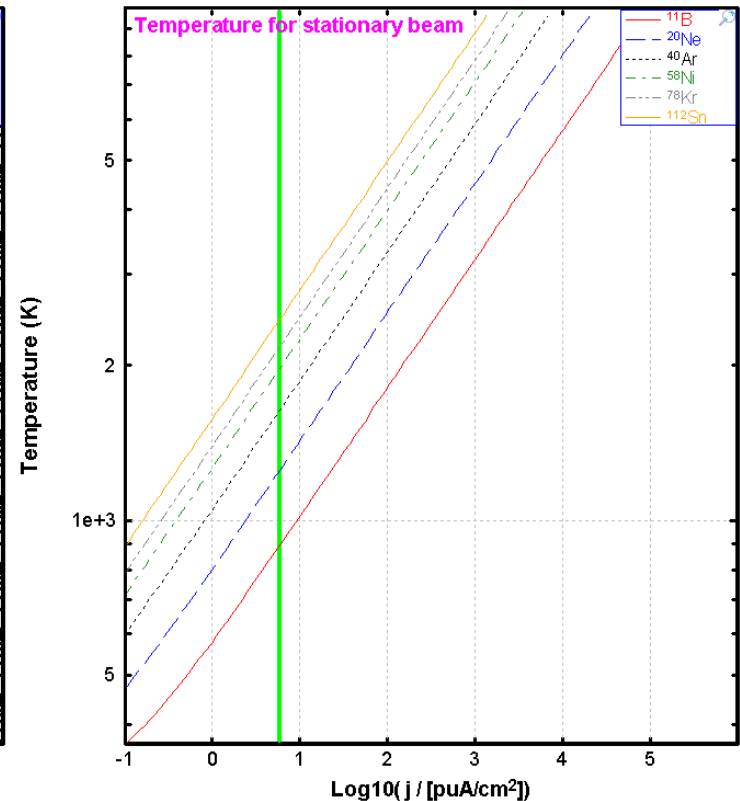
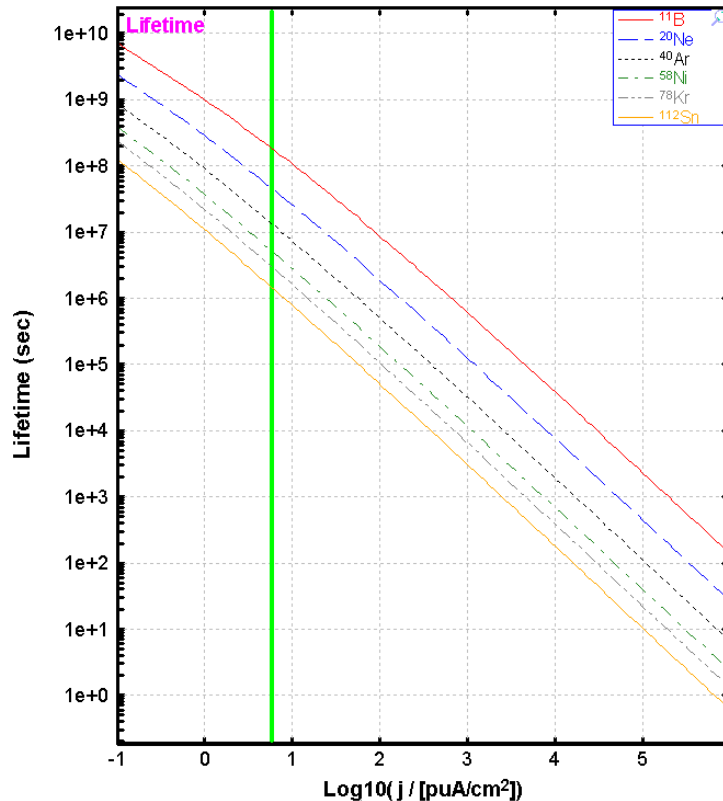
where  $P$  [W/cm<sup>2</sup>] is the beam power lost in a target, calculated by means of the LISE++ code

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

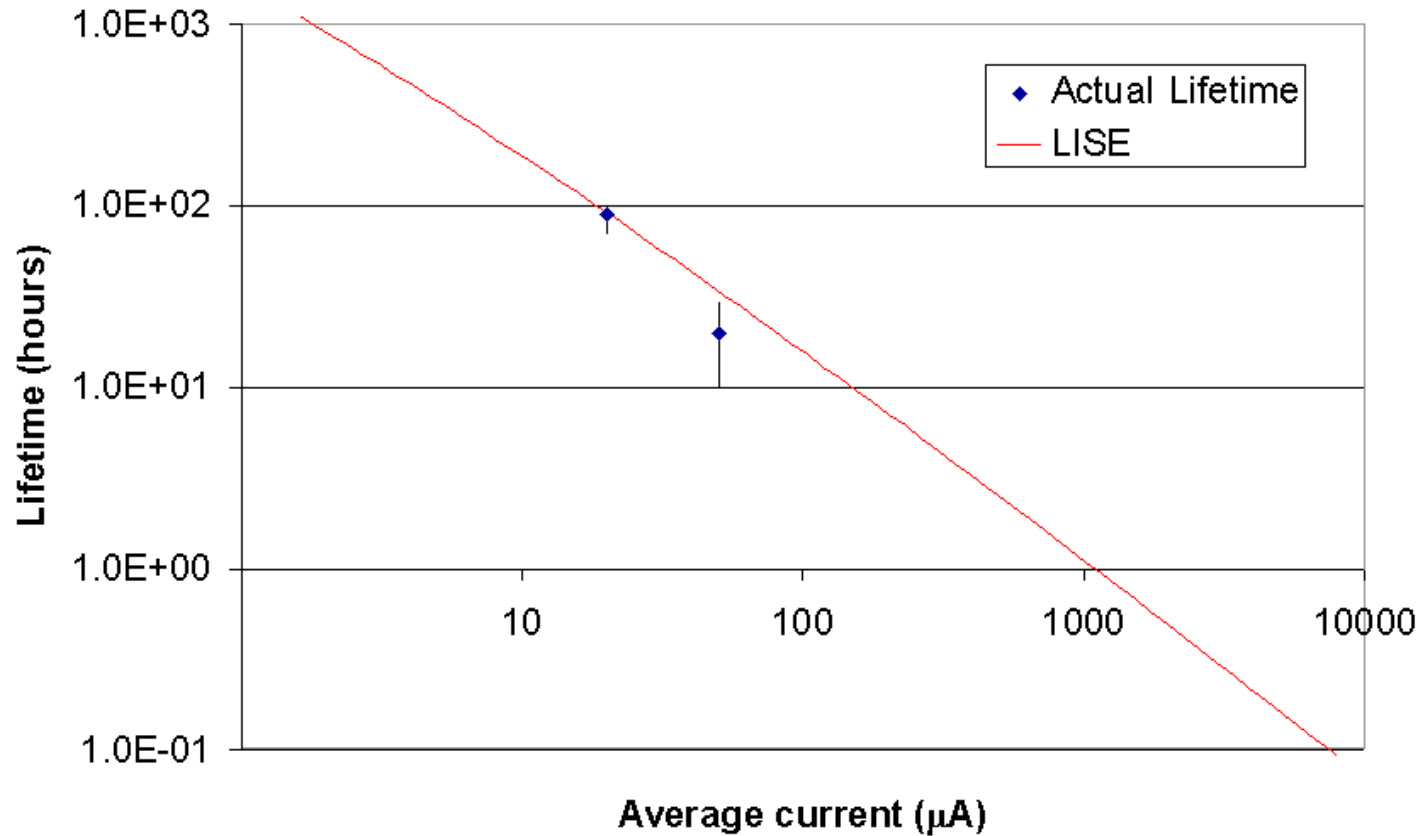
### Influence of radiation damages

Projectile Energy: 10.86 MeV/u    Foil: C (0.5 mg/cm<sup>2</sup>)

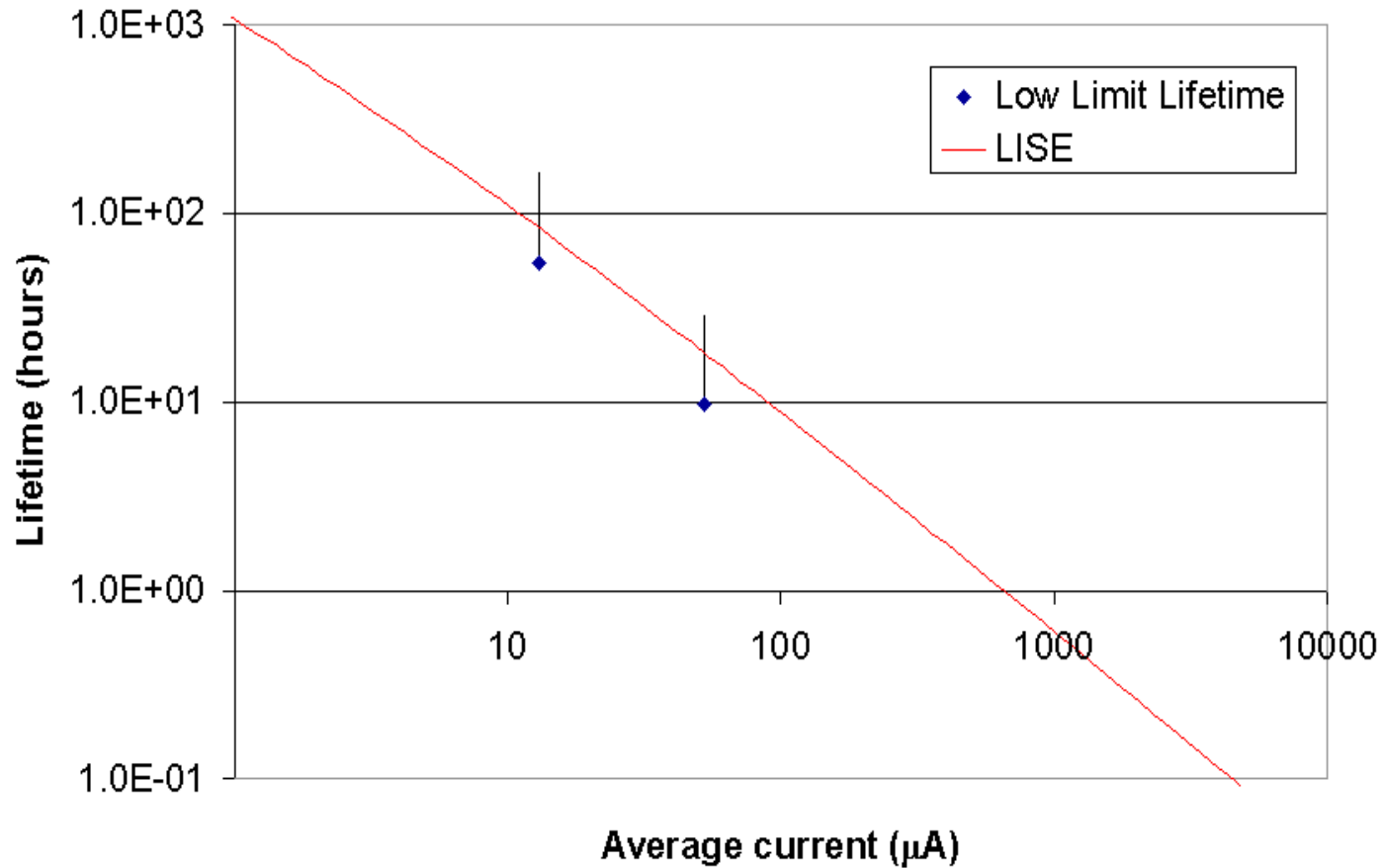
Left plot : Pulsing beam    On-off Ratio = 30.00%    Pulse length = 0.1 sec;    Repetition rate = 3 sec<sup>-1</sup>  
 epsilon=0.40    Displacement Energy=25.0    k1=50.0    k2=870.0



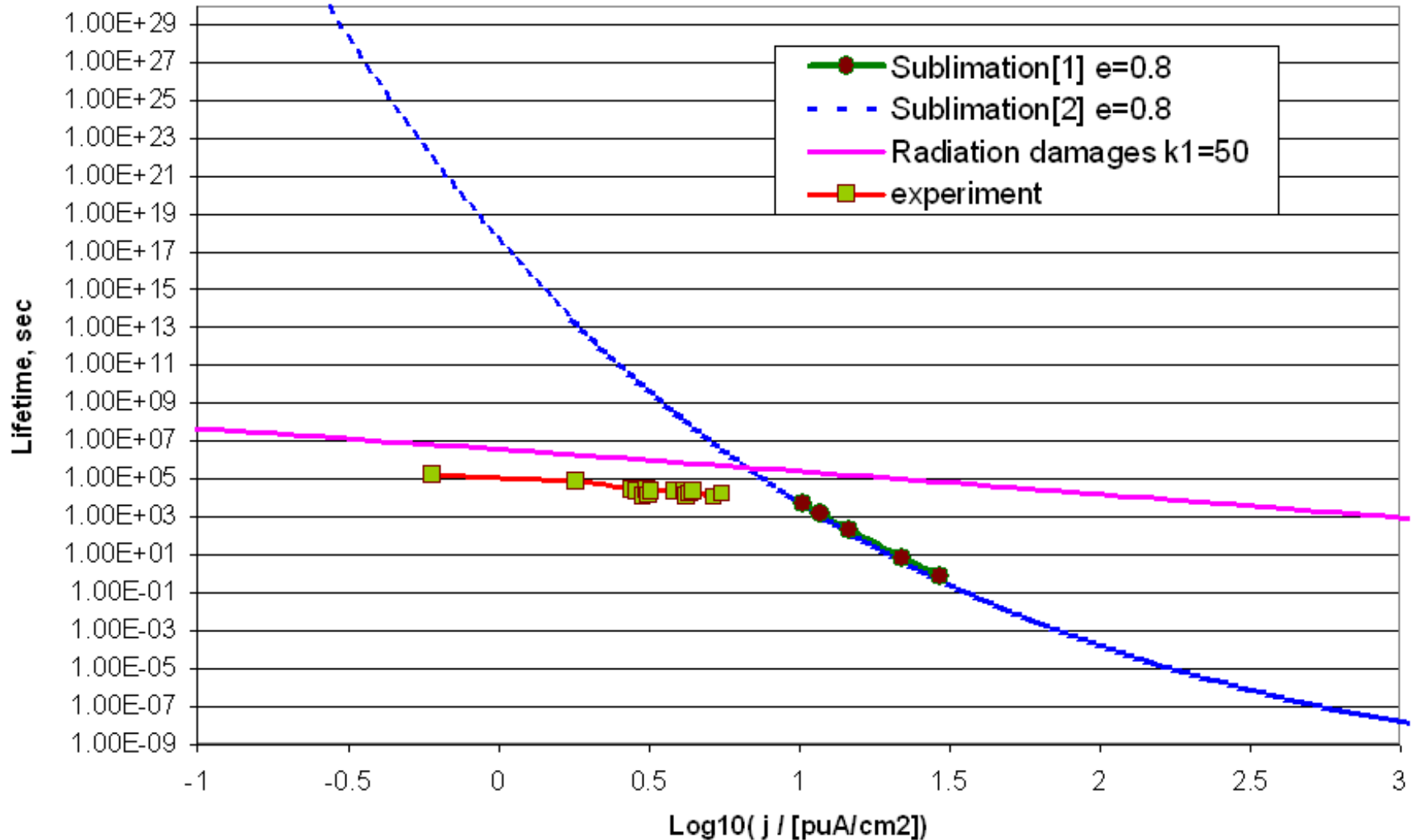
$^{40}\text{Ar}^{5+}$  5 MeV/u    Emiss. = 0.8  
 Beam size =  $0.5 \text{ cm}^2$     thick =  $50 \mu\text{g}/\text{cm}^2$



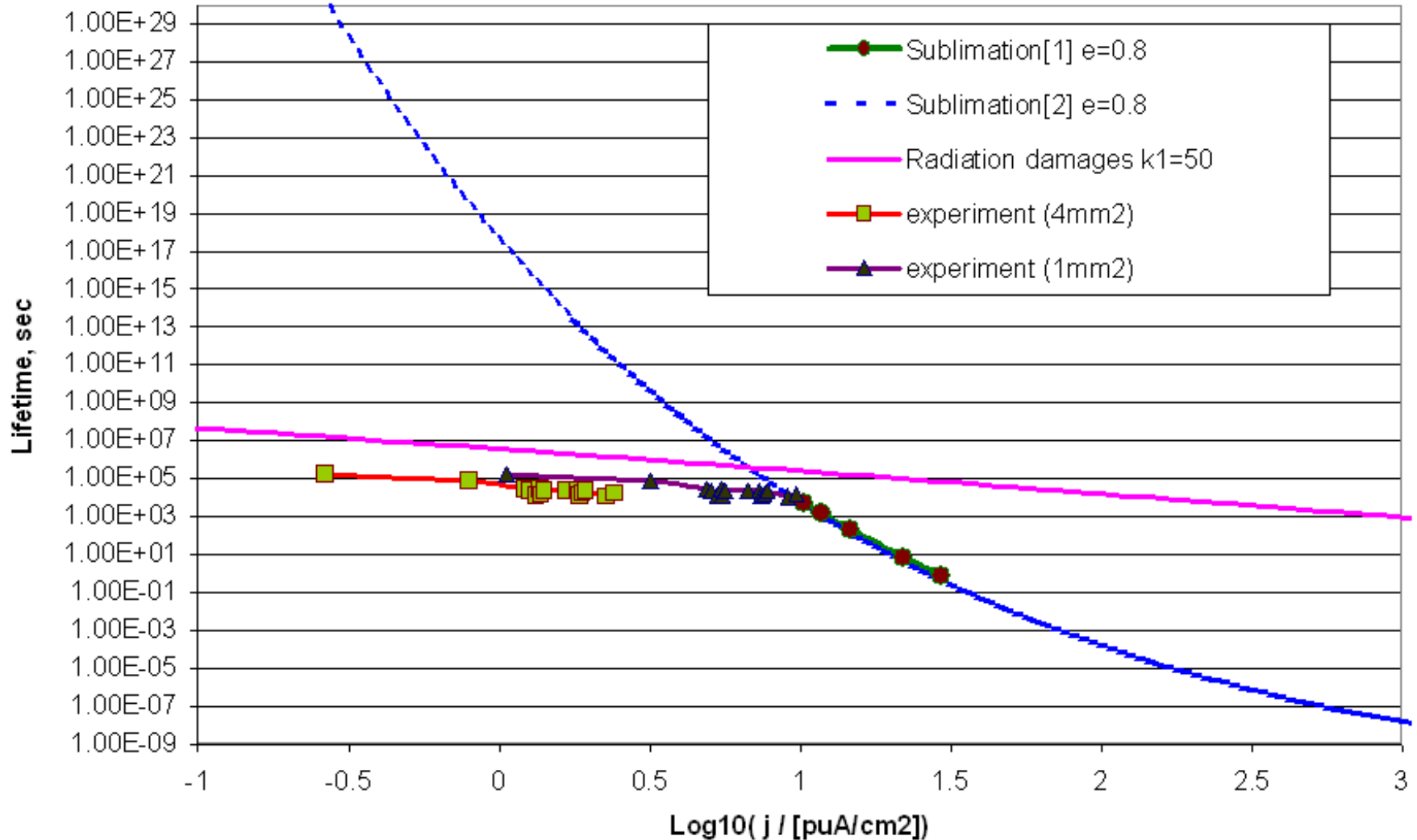
$^{20}\text{Ne}$  (5 MeV/u) Emiss. = 0.8  
 Beam size = 0.5 cm<sup>2</sup> thick=50 μg/cm<sup>2</sup>



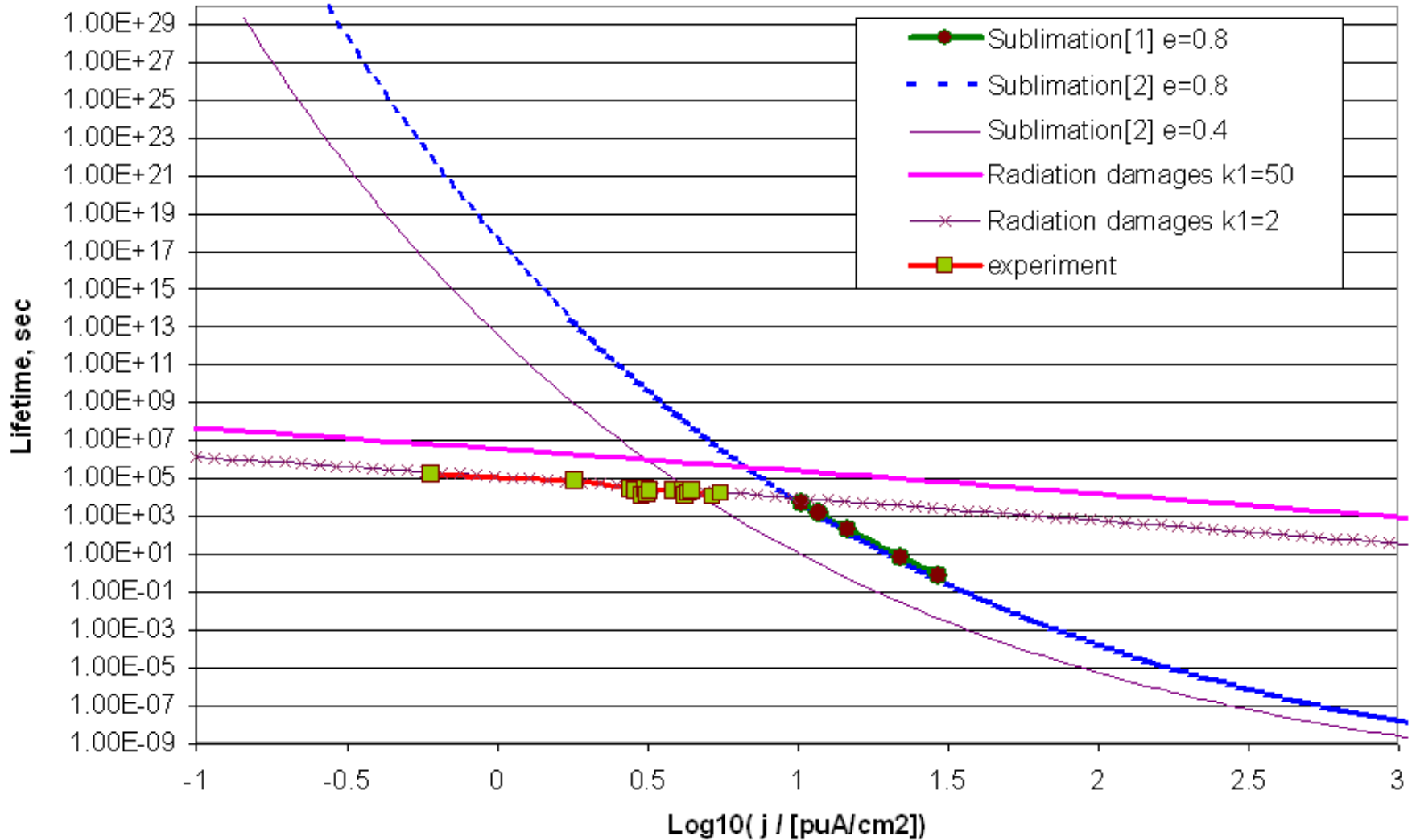
**112Sn 10.86 MeV/u**  
**Beam size = 4 mm2 (rectangle) C-thick=600 ug/cm2**  
**LISE++ version 8.3.6**



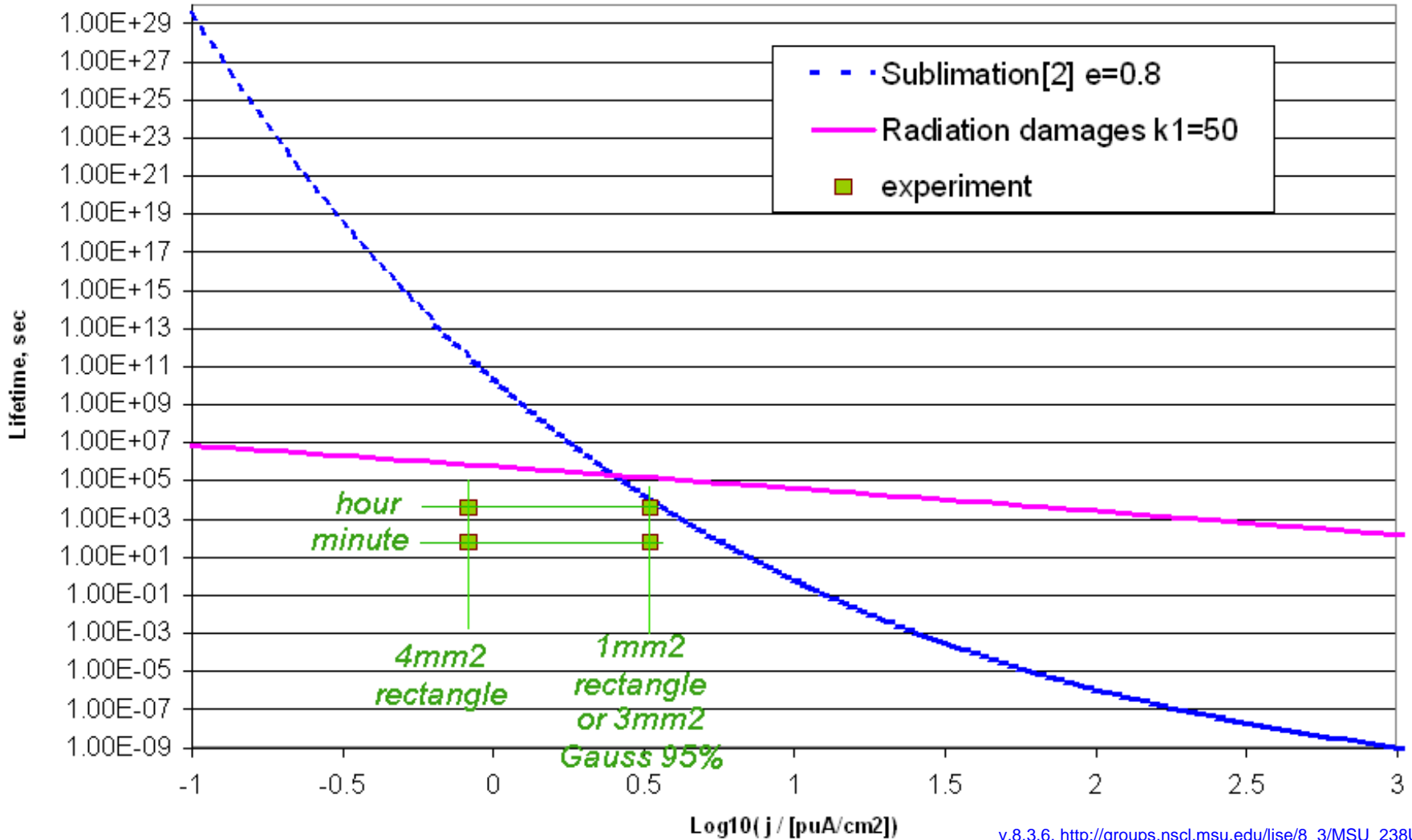
**112Sn 10.86 MeV/u**  
**Beam size = 4 mm<sup>2</sup> (rectangle) C-thick 600 ug/cm<sup>2</sup>**  
**LISE++ version 8.3.6**



**$^{112}\text{Sn}$  10.86 MeV/u**  
**Beam size = 4 mm<sup>2</sup> (rectangle) C-thick 600 u g/cm<sup>2</sup>**  
**LISE++ version 8.3.6**



**$^{238}\text{U}^{30+}$  7.68 MeV/u 1euA**  
**C-thick 600 ug/cm<sup>2</sup>**  
**LISE++ version 8.3.6**





238 U 30+ 7.68 MeV/u 1eUA  
C-thick 600 ug/cm2  
LISE++ version 8.3.6

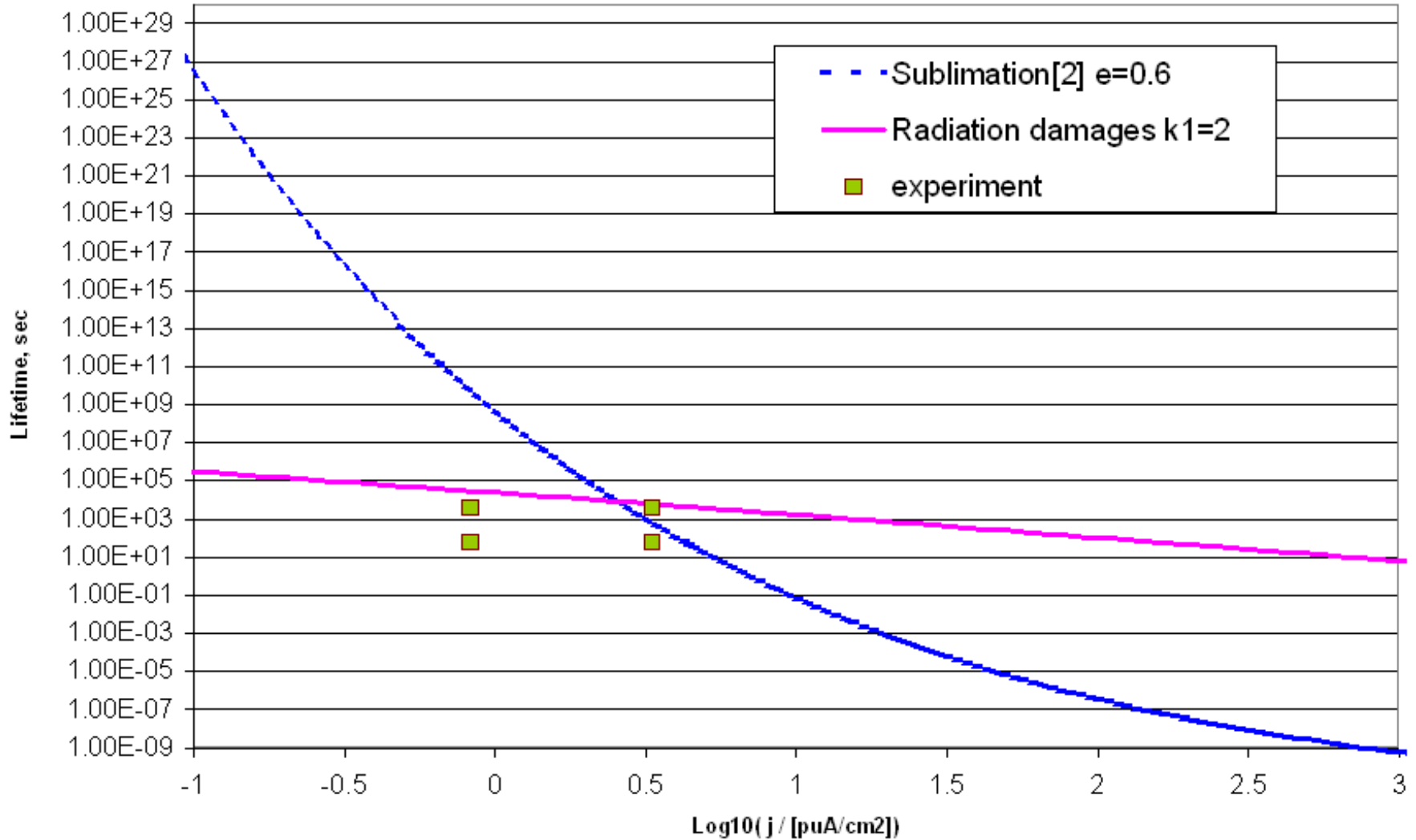


TABLE I. The parameters of  $H^-$  beams

	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

## Influence of sublimation (Pulsing beam [1]): Temperature

$^1\text{H}$  Projectile Energy: 0.75 MeV/u Foil: C (0.23 mg/cm<sup>2</sup>)

Left plot : Pulsing beam On-off Ratio = 0.34% Pulse length = 0.0005 sec; Repetition rate = 6.7 sec<sup>-1</sup>  
 Beam current = 2.2e+04 W/cm<sup>2</sup> or 3e+04 puA/cm<sup>2</sup>; epsilon=0.80

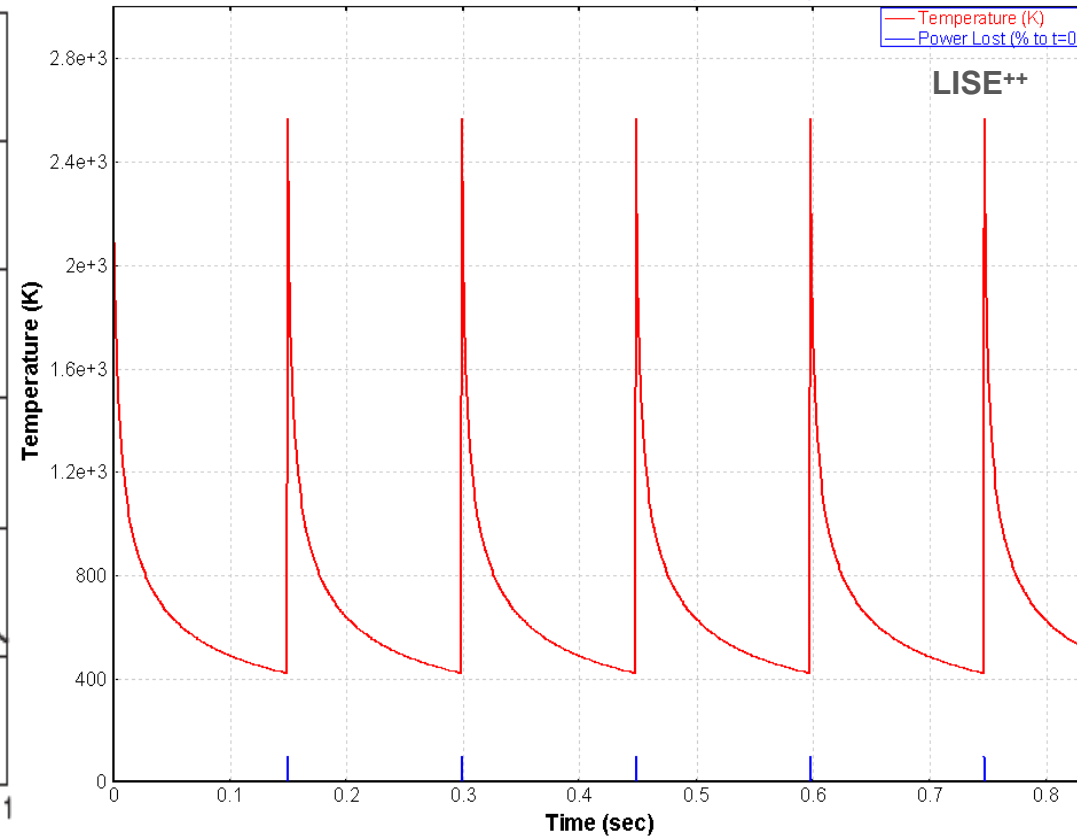
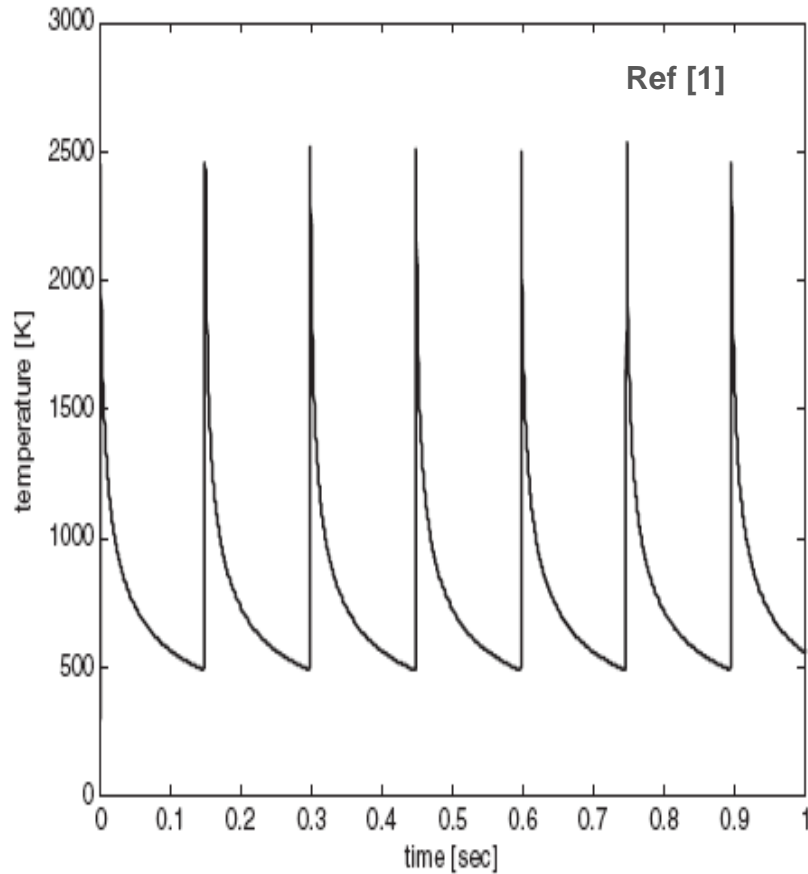
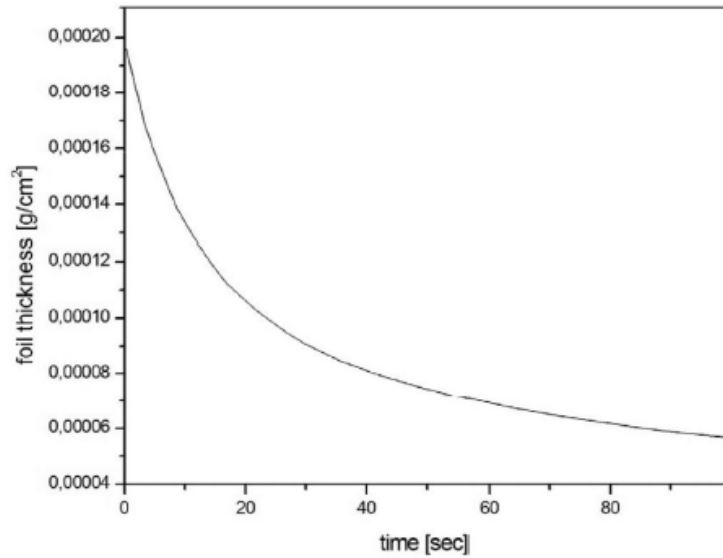
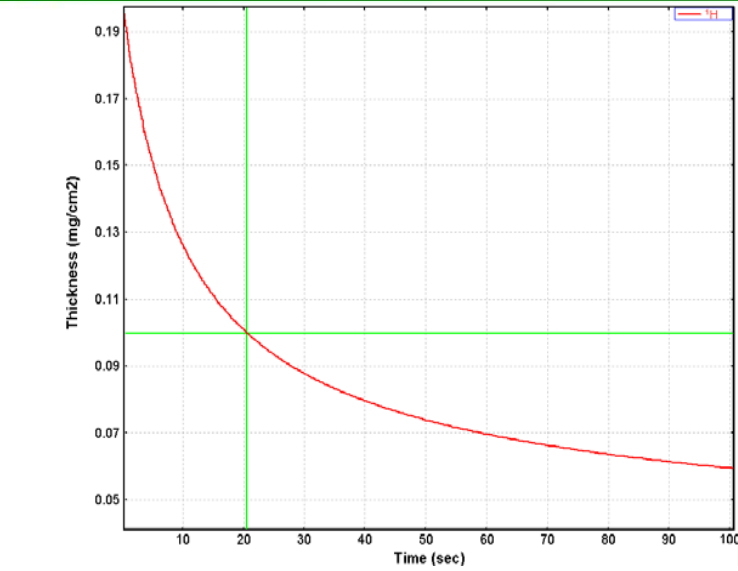
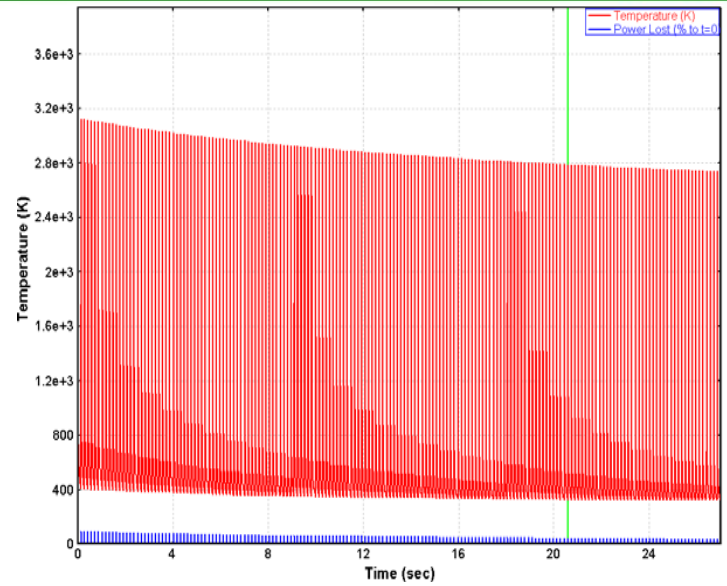


FIG. 1. A temperature field of a BNL linac target in the first second of work at a pulse current of 2 mA.



LISE++



Ref [1]

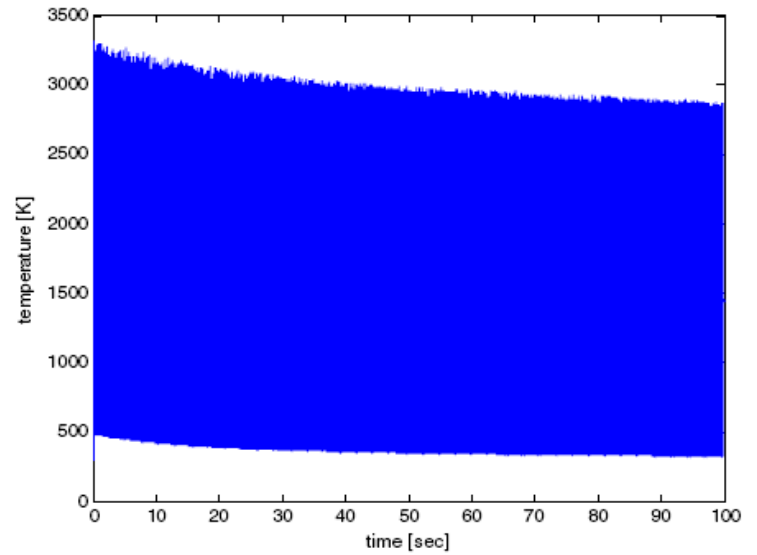


FIG. 2. Nonlinear foil thickness decreasing caused by the reduction of temperature at the BNL linac pulse current of 3 mA.

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.

**Choose a Plot Type**

Dimension of the plot  
 ONE-dimensional  
 TWO-dimensional  
 NZ chart

transmission characteristic to draw a plot  
 03 Sum of all reactions (pps)

Plot type  
 Isotopes, Z=const  
 Isobars, A=const  
 Isotones, N=const  
 Isospin, N-Z =const  
 N-ZZ=const  
 <N>/Z  
 sum(yalue); Z=const  
 sum(yalue); A=const  
 sum(yalue); N=const

Zmin = 16  
 Zmax = 16

function of  
 Z (protons)  
 A (nucleons)  
 N (neutrons)  
 N-Z (isospin)  
 N-ZZ

All  
 Odd  
 Even

OK Quit

Set the next parameters:  
 "2D", X="N", Y="Z", "N"=0-200

**Choose a Plot Type**

Dimension of the plot  
 ONE-dimensional  
 TWO-dimensional  
 NZ chart

transmission characteristic to draw a plot  
 03 Sum of all reactions (pps)

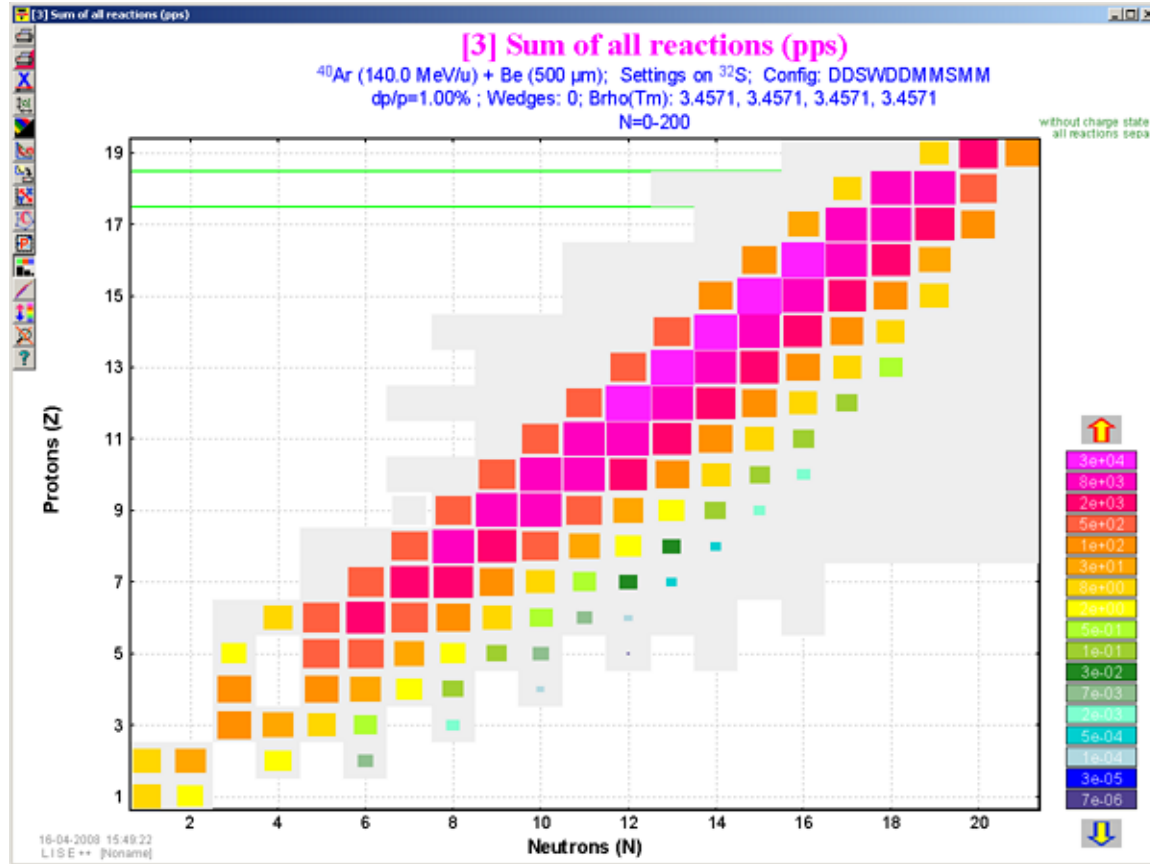
Plot type  
 Isotopes, Z=const  
 Isobars, A=const  
 Isotones, N=const  
 Isospin, N-Z =const  
 N-ZZ=const  
 <N>/Z  
 sum(yalue); Z=const  
 sum(yalue); A=const  
 sum(yalue); N=const

Nmin = 0  
 Nmax = 200

Vertical Axis  
 Z (protons)  
 A (nucleons)  
 N (neutrons)  
 N-Z (isospin)  
 N-ZZ

All  
 Odd  
 Even

OK Quit



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

Monte Carlo calculation of fragment transmission

A: 22, Element: S, Z: 16, Stable:

Charge states: 16+ D1

Reaction mechanism: Projectile Fragmentation

MC transmission options

"Distribution" calculation

**MC calculation to file**

Monte Carlo calculation 2D-plot

Add in the previous MC plot window

Quit

X-coordinate After BLOCK: D4

Y-coordinate After BLOCK: D4

Parameters: X, X'(T), Y, Y'(P), dP/P, R [f(X,Y)], A [f(X',Y')], Energy, TKE, Momentum, Brho, Velocity, Energy Loss, Range, Energy Deposition, Time of flight, Length

Gate: no gate

Rays generator

Setting Fragment: 32S16+..16+ Projectile Fragmentation

Gate: no gate

after BLOCK: D3

Output Ray file: MC\_LISE.ray

Run

Quit

File Format

Number of fields = 6 1..10

Header (settings, field names)

Field separator: tab

Field	Parameter
1	X [cm]
2	X'(Theta) [mrad]
3	Y [cm]
4	Y'(Phi) [mrad]
5	dP/P [%]
6	R [cm]

Number of Rays = 100 1..10 000

Make Default

Fixed Races

N / param	X	Theta	Y	Phi	Length	unused	Delta	Rmass
1	0	0	0	0	0	0	0	1
2	0	17.5	0	0	0	0	0	1
3	0	-17.5	0	0	0	0	0	1
4	0	0	0	0	0	0	4	1
5	0	0	0	0	0	0	-4	1

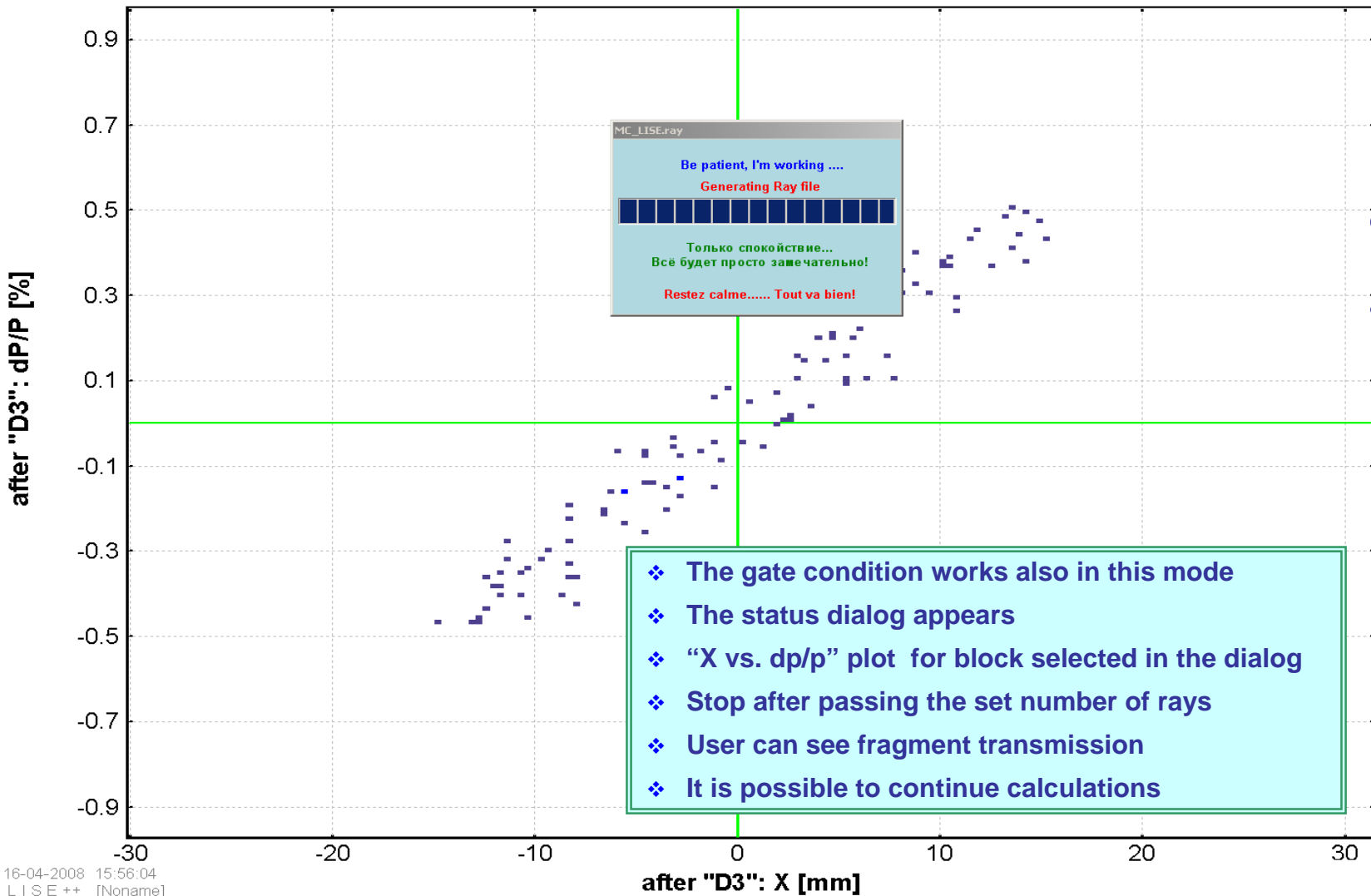
MOTER

OK Cancel Help

Continue

## **32S : Monte Carlo Transmission Plot**

$^{40}\text{Ar}$  (140.0 MeV/u) + Be (500  $\mu\text{m}$ ); Trasmitted Fragment  $^{32}\text{S}$  (Fragmentn)  
 dp/p=1.00% ; Wedges: 0; Brho(Tm): 3.4571, 3.4571, 3.4571, 3.4571  
 "D3" - last block for MC calculation; no gate; Configuration: DDSWDDMMMSMM



Default : "Lise / files" directory

File Extension: ".ray"

Number of fields =  1..10  
 Header (settings, field names)   
 Number of Rays =  1..10 000

Field separator   
 tab  
 semicolon  
 comma  
 space

Microsoft Excel - MC\_LISE.ray

File Edit View Insert Format Tools Data Window Help Adobe PDF

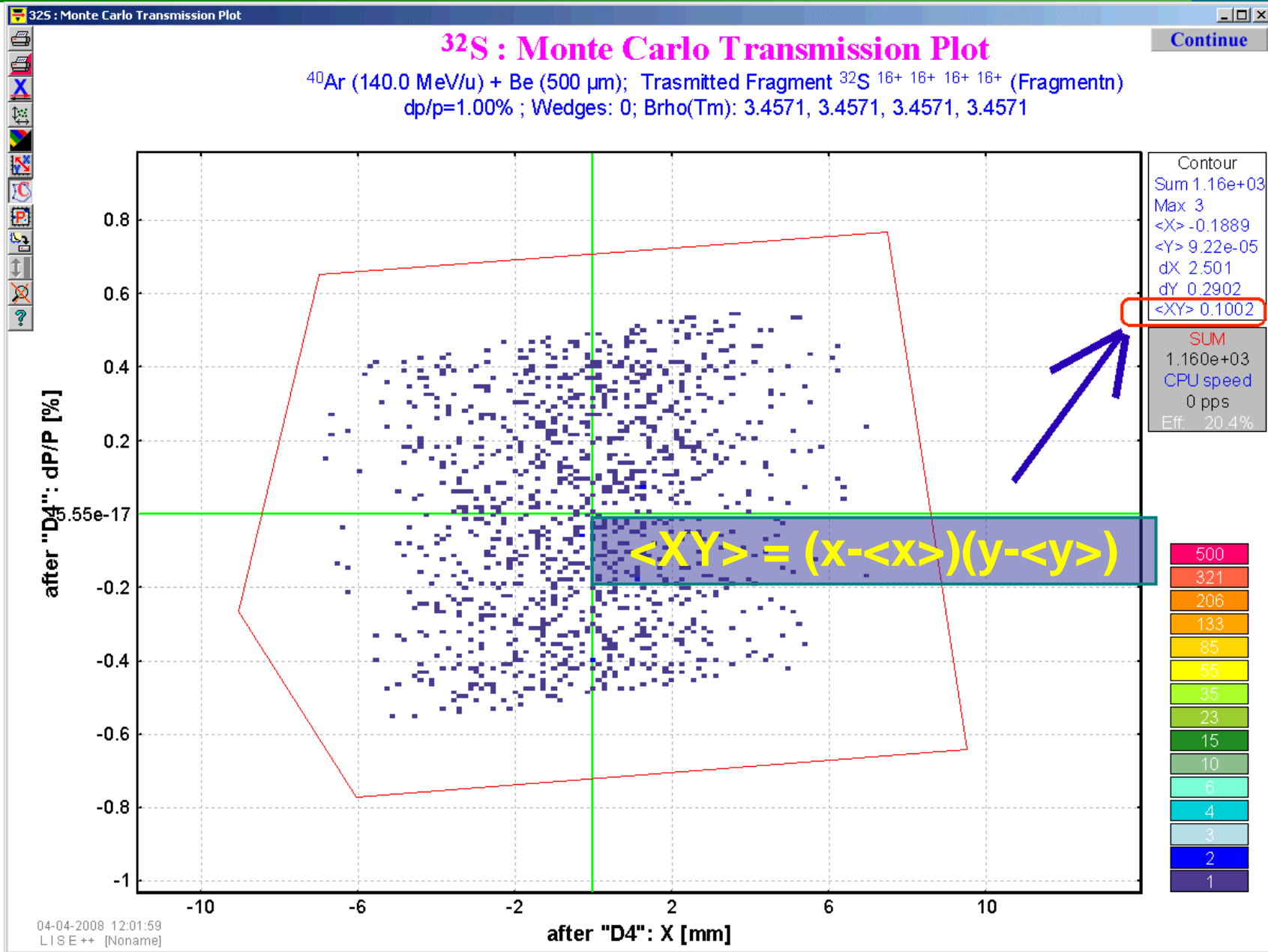
Arial 10 B I U

17 =

**Title**

	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

- Parameter
- X [cm]
  - X'(Theta) [mrad]
  - Y [cm]
  - Y'(Phi) [mrad]
  - dP/P [%]
  - R [cm]
  - A [mrad]
  - Energy [MeV/u]
  - TKE [MeV]
  - Momentum [GeV/c]
  - Brho [T\*m]
  - Length from Target [m]
  - Time from Target [ns]
  - Z (atomic number)
  - Q (ion charge)
  - Mass (amu)
  - 0 (empty)





- ❖ 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

$^{112}\text{Sn}$  @ MSU

$^{238}\text{U}$  @ MSU

$\text{H}^-$  @ BNL

$\text{H}^-$  @ SNS

## Analysis of some parameters

Current, Interaction area

Foil thickness

Beam energy

Emissivity factor

Heat capacity

Alpha

$k_1, k_2$

rotation target frequency

- ❖ Q3D configuration file (S.Lukyanov)
- ❖ Solenoid block (D.Morrissey)
- ❖ LISE++ site
  - FSEM08 presentation
  - Stripper foil lifetime utility
  - MOTER