Radiation dose due to Compton scattering by a grazing incidence mirror

M. R. Howells, July 8 1999

Introduction

This calculation was motivated by the need to know the radiation dose to the "O" rings proposed as water seals inside a steel mirror on a superbend protein crystallography beam line at the ALS. However, the calculation is more general and provides the dose to any target which is located at some given distance from a narrow beam of x-rays suffering a uniform rate of scatter per unit length of path. We focus attention on incoherent (Compton) scattering because this is the dominant process in iron for energies above 50 keV. It is also true that x-rays of 50 keV energy have a fractional penetration through one centimeter of iron of less than 10^{-6}. Thus we expect that the dose to a buried target in iron will be due to Compton scattering of x-rays of higher primary energy than 50 keV. However, since superbends produce significant output up to about 200 keV and since penetration increases very rapidly (roughly as the third power) with energy, we need to estimate the dose to the "O" rings.

We consider an infinitely long mirror with very grazing x-ray illumination which is the same everywhere along a narrow illuminated stripe represented by the line PO in the diagram in the spreadsheet. It is a direct consequence of this assumption that, for each incident energy, the number of Compton-scattered x-rays emanating from a one-centimeter segment (at P say) of the illuminated stripe is equal to the arrival rate into that segment times the probability that Compton scattering will be the outcome. This accounts for the fact that x-rays which arrive at P and scatter further downstream are balanced by ones which arrive further upstream and scatter at P.

Calculation of the x-ray flux per unit area at the target

The basic data we have used in the calculation are

- The incoherent cross sections σ_{inc} integrated over all angles (taken from W. H. McMaster, Compilation of x-ray cross sections UCRL-50174-SEC 2-R1, Lawrence Livermore Laboratory, 1969).
- The total cross sections σ_{tot} (also taken from McMaster)
- The spectral flux per unit solid angle (F) of an ALS superbend (taken from a standard calculation by the author).

After importing these data, the calculation proceeds as follows (see spreadsheet).

1. The number of photons arriving per centimeter of mirror length per actual bandwidth per second $F_{\mathrm{m}}(E)$ is calculated. This is obtained geometrically from the spectral flux per unit solid angle delivered by the source. The actual bandwidth is the interval to the next data point so that later we can sum over the spectrum without gaps.
2. Using the conclusion of the second paragraph of the introduction, calculate the Compton emission rate F_{C} in photons per second per centimeter of mirror length per actual bandwidth as

$$F_{\mathrm{C}} = F_{\mathrm{m}} \frac{\sigma_{\mathrm{inc}}}{\sigma_{\mathrm{tot}}}$$

3. The number of photons per square centimeter per second per actual bandwidth $F_{\mathrm{T}}(x)$ reaching the target from a given one-centimeter segment of the illuminated stripe, distant x from the origin, is thus

$$F_{\mathrm{T}}(x) = F_{\mathrm{C}} \frac{\left.\frac{\partial\sigma}{\partial\Omega}\right|_{\theta}}{\sigma_{\mathrm{inc}}} \Delta\Omega \; e^{-\sigma_{\mathrm{tot}}\rho r} = F_{\mathrm{m}} \frac{\left.\frac{\partial\sigma}{\partial\Omega}\right|_{\theta}}{\sigma_{\mathrm{tot}}} \frac{\varepsilon^2}{r^2} \; e^{-\sigma_{\mathrm{tot}}\rho r}$$

The quantities θ and r are obtained geometrically from the current value of x and the impact parameter b which is the perpendicular distance from the illuminated stripe to the target (see the diagram in the attached spread sheet). Since *all* the photons counted in F_{C} are Compton scattered the angular distribution is given by the second term of the above equation where $\left.\frac{\partial\sigma}{\partial\Omega}\right|_{\theta}$ is the Klein Nishina cross section (see for example A. E. S. Green, "Nuclear Physics", McGraw-Hill, New York, 1955)

$$\left.\frac{\partial\sigma}{\partial\Omega}\right|_{\theta} = \frac{3\sigma_{\mathrm{e}}}{16\pi} \frac{1+\cos^2\theta}{\left[1+\zeta(1-\cos\theta)\right]^3} \left\{ \frac{\zeta^2(1-\cos\theta)^2}{\left(1+\cos^2\theta\right)\left[1+\zeta(1-\cos\theta)\right]} \right\},$$

where $\sigma_{\mathrm{e}} = \frac{8\pi e^2}{3 m_0 c^2}$ is the Thompson cross section and $\zeta = E/m_0 c^2$ in usual notation. The target size ε^2 we take to be one square centimeter and the exponential factor represents extinction of the scattered beam on its way to the target. The cross section σ_{tot} in the exponent is therefore to be evaluated at the *scattered energy* E'. Since both the incident energy and the angle are defined, E' can be obtained from

$$E' = \frac{E}{1 + \zeta(1 - \cos\theta)}$$

Note that σ_{inc} cancels out and is not really needed although it helps to make the calculation more readable.

Derivation of the dose

The calculation of the dose can be accomplished most easily using the so-called "incoherent-scattering energy-absorption cross section" σ_{ea}^{inc}. This quantity is obtained by multiplying the differential incoherent scattering cross section by the fraction of the photon energy absorbed by the scattering atom and integrating over all angles. Analytical approximations for σ_{ea}^{inc} in cm^2/gm are given in F. Biggs and R. Lighthill, "Analytical approximations for total and energy absorption cross sections for photon-atom scattering", Research report SC-RR-72 0685, Sandia Laboratories, 1972 as follows.

$$\sigma_{ea}^{inc} = \sigma_{ea}^{KN} \frac{Z}{A} D(E)$$

where σ_{ea}^{KN} is the corresponding Klein-Nishina cross section in units of cm^2 per mole of electrons which is approximated by

$$\sigma_{ea}^{KN} = 0.4006 \left\{ \frac{\varsigma + 0.825\varsigma^2 + 0.03234\varsigma^3}{1 + 5.393\varsigma + 5.212\varsigma^2 + 0.8783\varsigma^3 + 0.01599\varsigma^4} \right\}.$$

Z and A are the atomic number and gram atomic weight respectively and $D(E)$ is a dimensionless binding energy correction factor. Since we are dealing entirely with energies that are far above the K threshold of iron we take $D(E)$ to be equal to unity. We now have σ_{ea}^{inc} and therefore

$$I = I_0 e^{-\sigma_{ea}^{inc}\rho x} \text{ whence } \left.\frac{\partial I}{\partial x}\right|_{x=0} = -I_0 \sigma_{ea}^{inc} \rho .$$

where I and I_0 are energy fluxes in watts/cm^2. The derivative in this expression gives the rate of energy deposition at x=0, i. e. when the beam is not yet attenuated, in watts/cm^3. The dose rate in watts/gm is thus $I_0 \sigma_{ea}^{inc}$ so that, using 1 Gy=1 J/kgm and 1 rad=0.01 Gy, we have

$$\text{Dose rate (rad/sec)} = 10^5 F_T(x)\, E'\, \sigma_{ea}^{inc}$$

where E' is now expressed in Joules.

Results

So first we have the flux on target per cm of illuminated stripe for each primary x-ray energy and each upstream distance *x* of the point of scatter from the target. The following features can be noted

- Only portions of the illuminated stripe which are within a distance of about *b* to 2*b* from the origin contribute significantly (*b* is the origin-to-target distance and we show the realistic case *b*=3 cm in the spread sheet).
- Only the spectral region of 100–200 keV contributes significantly to the dose. Below 100 keV the penetration is insufficient while above 200 keV the source output is too weak.

It is noteworthy that the x-ray dose rate to the target depends only on the number of electrons per unit mass of the target, i. e. on its *Z/A* value, which varies little with composition and not at all with density. Thus we take the target to be made of nitrogen of unspecified density. The dose rate due to all distances *x* at given primary energy and due to all primary energies at given distance *x* are found by summing the rows and columns respectively of the spreadsheet. The final overall total dose rate is then derived (bottom right corner) and, given the allowed dose to the “O” ring [from DiGennaro], one can calculate its expected useful life. This comes to some millions of years. In light of this we do not discuss in detail the basis on which the “O” ring allowed dose was estimated nor do we show in detail the dose-rate contributions due to points downstream of the target. The latter can be shown to be less than the contributions we did include due to the increase of forward scattering relative to backscattering as the primary energy increases.

Additional applications of the calculation

This same procedure with only minor changes can be used to calculate the amount of scattered energy and hence the heating effect on the side of the beam opposite to the mirror.

Calculation for a silicon mirror.

It is of interest to repeat this calculation for a silicon mirror. This is in part because silicon mirrors are commonly used but also to test whether the calculation correctly predicts the behavior which we observed at the temporary silicon mirror on beam line 5.0.2, namely that the “O” ring leaked after a few months exposure.

First the calculation for the iron mirror was repeated with no change except the replacement of iron by silicon. That is the superbend source and geometry were both kept the same. The result was a lifetime of 71 years and the most significant part of the spectrum for dose production was 50-100 keV. Secondly the calculation was repeated with the same source and a distance (*b*) from the illuminated stripe to the “O” ring of 0.3 cm which is roughly the beam-line 5.0.2 value. The lifetime in this case was 0.12 year in good qualitative agreement with observation. Note that the wiggler source at beam line 5.0.2 is not identical to the superbend source. The wiggler flux is higher up to about 30 keV and lower beyond.

COMPTON SCATTERING CALCULATION
M. Howells, 7-1-99

Incoherent and total cross sections from McMaster

Source mirror distance (m)	6.5	
Grazing angle (rad)	0.0045	
Beam width (cm)	1	
mr H	3	
mrV (to illuminate 1 cm of mir)	0.006923077	(calculated)
Impact parameter (cm)	3	
Target size (cm)	1	(do not change)
Conversion factor C (Fe)	92.74	
Thompson sigma (barns/e-)	0.6652	
Atomic number (Fe)	26	
Electron rest mass (keV)	511	
Thickness (cm)	1	
Density W (g/cc)	19.3	
Density Fe (g/cc)	7.86	
Target atomic number	7	
Target atomic weight	14.007	
Allowed dose (rad)	5.000E+08	

Note: input data yellow
independent variables blue

Note: The Compton dose depends only on the number of electrons per unit mass of the target - ie on Z/A which varies little with composition and not at all with density

Definitions:
sigma(barns/atom)=C*sigma(cm^2/gm)
x=distance from the current impact point to the origin (cm)
(which is opposite the target)
r=distance from the current impact point direct to the target (cm)
theta= angle between r and x

ALS 1.9 GeV
Ecrit=12 keV
I=0.4 Amp

Calculation of scatttered energy

E (keV) incident	E' (keV) at x, r, theta (see H23:H25)	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->
10	9.99E+00	9.99E+00	9.99E+00	9.98E+00	9.98E+00	9.97E+00	9.96E+00	9.94E+00	9.91E+00	9.87E+00	9.81E+00
15	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.49E+01	1.49E+01	1.49E+01	1.48E+01	1.47E+01	1.46E+01
20	2.00E+01	2.00E+01	2.00E+01	1.99E+01	1.99E+01	1.99E+01	1.98E+01	1.98E+01	1.97E+01	1.95E+01	1.92E+01
30	2.99E+01	2.99E+01	2.99E+01	2.99E+01	2.98E+01	2.98E+01	2.97E+01	2.95E+01	2.92E+01	2.88E+01	2.83E+01
40	3.99E+01	3.98E+01	3.98E+01	3.97E+01	3.97E+01	3.96E+01	3.94E+01	3.91E+01	3.87E+01	3.80E+01	3.71E+01
50	4.98E+01	4.98E+01	4.97E+01	4.96E+01	4.95E+01	4.93E+01	4.90E+01	4.86E+01	4.79E+01	4.69E+01	4.55E+01
60	5.97E+01	5.96E+01	5.96E+01	5.94E+01	5.93E+01	5.90E+01	5.86E+01	5.80E+01	5.70E+01	5.55E+01	5.37E+01
80	7.95E+01	7.94E+01	7.92E+01	7.90E+01	7.87E+01	7.83E+01	7.76E+01	7.65E+01	7.48E+01	7.23E+01	6.92E+01
100	9.92E+01	9.90E+01	9.88E+01	9.84E+01	9.80E+01	9.73E+01	9.62E+01	9.46E+01	9.20E+01	8.82E+01	8.36E+01
150	1.48E+02	1.48E+02	1.47E+02	1.47E+02	1.45E+02	1.44E+02	1.42E+02	1.38E+02	1.33E+02	1.25E+02	1.16E+02
200	1.97E+02	1.96E+02	1.95E+02	1.94E+02	1.92E+02	1.89E+02	1.85E+02	1.79E+02	1.70E+02	1.58E+02	1.44E+02
300	2.93E+02	2.91E+02	2.89E+02	2.86E+02	2.82E+02	2.77E+02	2.68E+02	2.56E+02	2.38E+02	2.14E+02	1.89E+02
400	3.87E+02	3.85E+02	3.81E+02	3.76E+02	3.69E+02	3.60E+02	3.46E+02	3.25E+02	2.97E+02	2.61E+02	2.24E+02
500	4.80E+02	4.76E+02	4.71E+02	4.63E+02	4.53E+02	4.39E+02	4.18E+02	3.89E+02	3.48E+02	3.00E+02	2.53E+02
600	5.72E+02	5.66E+02	5.58E+02	5.48E+02	5.34E+02	5.14E+02	4.86E+02	4.46E+02	3.94E+02	3.33E+02	2.76E+02
800	7.50E+02	7.41E+02	7.27E+02	7.10E+02	6.87E+02	6.54E+02	6.09E+02	5.48E+02	4.71E+02	3.86E+02	3.12E+02
1000	9.24E+02	9.09E+02	8.89E+02	8.63E+02	8.29E+02	7.82E+02	7.19E+02	6.36E+02	5.34E+02	4.28E+02	3.38E+02

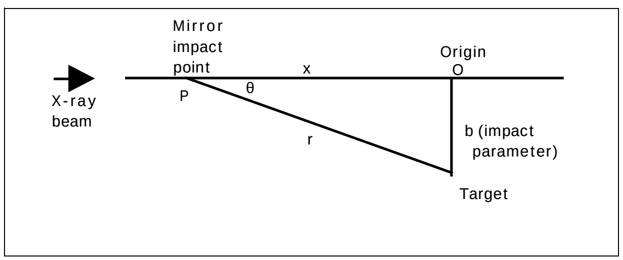
x=-->	1.00E+01	9.00E+00	8.00E+00	7.00E+00	6.00E+00	5.00E+00	4.00E+00	3.00E+00	2.00E+00	1.00E+00	0.00E+00
r=-->	1.04E+01	9.49E+00	8.54E+00	7.62E+00	6.71E+00	5.83E+00	5.00E+00	4.24E+00	3.61E+00	3.16E+00	3.00E+00
cos(theta)=-->	9.58E-01	9.49E-01	9.36E-01	9.19E-01	8.94E-01	8.57E-01	8.00E-01	7.07E-01	5.55E-01	3.16E-01	0.00E+00

E(keV)	Iron Incoherent xsect cm^2/gm	Iron Total xsect cm^2/gm	Flux/unit solid angle (ph/s/mr^2/0.1%BW)	ph/s/cm of mir length/ actual BW (meaning the interval to the previous energy)	Compton portion (same units)
10	0.08504	172.8	2.825E+13		
15	0.1046	57.66	2.626E+13	1.818E+14	3.298E+11
20	0.1165	25.75	2.225E+13	1.155E+14	5.226E+11
30	0.1284	8.087	1.390E+13	9.620E+13	1.527E+12
40	0.1338	3.559	7.858E+12	4.080E+13	1.534E+12
50	0.1357	1.911	4.202E+12	1.745E+13	1.239E+12
60	0.1357	1.174	2.167E+12	7.501E+12	8.670E+11
80	0.1334	0.5806	5.377E+11	2.792E+12	6.415E+11
100	0.1298	0.3643	1.258E+11	5.224E+11	1.861E+11
150	0.1202	0.1946	2.887E+09	1.998E+10	1.234E+10
200	0.1114	0.1452	5.926E+07	3.077E+08	2.361E+08
300	0.09788	0.1095	2.121E+04	1.468E+05	1.313E+05
400	0.08809	0.09372	6.960E+00	3.614E+01	3.397E+01
500	0.08062	0.08389	2.198E-03	9.132E-03	8.776E-03
600	0.07467	0.0768	6.822E-07	2.361E-06	2.296E-06
800	0.06569	0.06678	6.293E-14	3.267E-13	3.214E-13
1000	0.05909	0.05975	5.466E-21	2.271E-20	2.246E-20

Flux on target (p/s/actual BW)

	Flux on target (p/s/actual BW)	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->
15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
30	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.42E-268	2.50E-254
40	1.37E-279	3.44E-253	4.45E-227	2.31E-201	3.27E-176	6.82E-152	7.51E-129	7.54E-108	3.40E-90	6.09E-78	1.74E-73
50	2.57E-118	1.18E-106	4.07E-95	9.48E-84	1.26E-72	7.21E-62	1.13E-51	2.23E-42	1.42E-34	3.53E-29	3.08E-27
60	9.67E-60	1.92E-53	3.29E-47	4.59E-41	4.77E-35	3.17E-29	1.05E-23	1.13E-18	1.86E-14	1.47E-11	1.54E-10
80	1.34E-33	1.06E-29	7.68E-26	4.95E-22	2.67E-18	1.10E-14	2.94E-11	3.88E-08	1.57E-05	9.30E-04	3.73E-03
100	5.57E-13	5.16E-11	4.61E-09	3.90E-07	3.04E-05	2.08E-03	1.15E-01	4.40E+00	8.98E+01	6.60E+02	1.21E+03 *
150	2.01E-06	3.68E-05	6.59E-04	1.15E-02	1.90E-01	2.90E+00	3.83E+01	3.96E+02	2.64E+03	8.74E+03	1.16E+04 *
200	4.59E-02	2.34E-01	1.19E+00	5.97E+00	2.93E+01	1.37E+02	5.91E+02	2.17E+03	6.02E+03	1.06E+04	2.01E+02 *
300	1.63E-03	5.73E-03	2.00E-02	6.95E-02	2.36E-01	7.74E-01	2.35E+00	6.20E+00	1.27E+01	1.78E+01	5.13E+00
400	8.58E-06	2.29E-05	6.11E-05	1.62E-04	4.22E-04	1.06E-03	2.49E-03	5.14E-03	3.07E-03	4.13E-03	3.69E-03
500	8.64E-09	2.04E-08	4.81E-08	1.13E-07	2.59E-07	5.75E-07	1.19E-06	1.28E-06	2.04E-06	9.65E-07	8.41E-07
600	5.34E-12	1.17E-11	2.54E-11	5.49E-11	1.17E-10	2.38E-10	3.08E-10	5.46E-10	4.98E-10	5.60E-10	1.97E-10
800	1.45E-18	2.98E-18	6.09E-18	1.23E-17	2.43E-17	4.60E-17	8.06E-17	9.77E-17	9.59E-17	6.67E-17	5.30E-17
1000	2.45E-25	4.63E-25	8.69E-25	1.61E-24	2.90E-24	3.16E-24	5.37E-24	7.96E-24	7.89E-24	6.01E-24	3.16E-24

	Dose in rad/sec	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->
10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0
15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0
20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.86E-280	0
30	1.00E-290	2.52E-264	3.25E-238	1.68E-212	2.37E-187	4.92E-163	5.37E-140	5.33E-119	2.36E-101	4.09E-89	1.6116E-265
40	2.74E-129	1.26E-117	4.33E-106	1.00E-94	1.33E-83	7.57E-73	1.18E-62	2.28E-53	1.42E-45	3.40E-40	1.59408E-84
50	1.39E-70	2.76E-64	4.72E-58	6.57E-52	6.79E-46	4.48E-40	1.47E-34	1.55E-29	2.48E-25	1.88E-22	3.7274E-38
60	3.04E-44	2.40E-40	1.74E-36	1.11E-32	5.97E-29	2.44E-25	6.43E-22	8.32E-19	3.24E-16	1.82E-14	2.82051E-21
80	1.78E-23	1.64E-21	1.46E-19	1.23E-17	9.53E-16	6.45E-14	3.50E-12	1.31E-10	2.56E-09	1.76E-08	9.17231E-14
100	1.14E-16	2.07E-15	3.70E-14	6.39E-13	1.05E-11	1.58E-10	2.04E-09	2.03E-08	1.28E-07	3.90E-07	4.864E-08
150	3.78E-12	1.92E-11	9.69E-11	4.83E-10	2.34E-09	1.08E-08	4.51E-08	1.59E-07	4.11E-07	6.55E-07	6.31715E-07
200	2.18E-13	7.61E-13	2.64E-12	9.06E-12	3.03E-11	9.69E-11	2.84E-10	7.08E-10	1.33E-09	1.64E-09	1.57137E-08
300	1.57E-15	4.16E-15	1.10E-14	2.87E-14	7.33E-14	1.79E-13	4.03E-13	7.75E-13	4.17E-13	4.82E-13	4.99065E-10
400	1.98E-18	4.63E-18	1.08E-17	2.48E-17	5.59E-17	1.20E-16	2.36E-16	2.35E-16	3.31E-16	1.33E-16	4.14268E-13
500	1.45E-21	3.14E-21	6.75E-21	1.43E-20	2.96E-20	5.83E-20	7.13E-20	1.16E-19	9.27E-20	8.66E-20	1.04912E-16
600	5.09E-28	1.03E-27	2.07E-27	4.10E-27	7.86E-27	1.42E-26	2.33E-26	2.55E-26	2.15E-26	1.22E-26	2.83252E-20
800	1.03E-34	1.92E-34	3.53E-34	6.37E-34	1.11E-33	1.15E-33	1.81E-33	2.40E-33	2.01E-33	1.22E-33	8.34622E-27
1000											
Total dose all energies (rad) due to arriving x-rays at x ------------------>	4.00E-12	2.00E-11	9.96E-11	4.92E-10	2.38E-09	1.10E-08	4.74E-08	1.80E-07	5.43E-07	1.06E-06	6.97E-07



Total dose all energies and arrival points (rads/sec)	2.55E-06
Time for allowed dose (years)	6.23E+06

COMPTON SCATTERING CALCULATION
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Grazing angle (rad)	0.0045	
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Impact parameter (cm)	3	
Target size (cm)	1	(do not change)
Conversion factor C (Si)	46.63	
Thompson sigma (barns/e-)	0.6652	
Atomic number (Si)	14	
Electron rest mass (keV)	511	
Thickness (cm)	1	
Density W (g/cc)	19.3	
Density Si (g/cc)	2.33	
Target atomic number	7	
Target atomic weight	14.007	
Allowed dose (rad)	5.000E+08	

Note: input data yellow
independent variables blue

Note: The Compton dose depends only on the number of electrons per unit mass of the target - ie on Z/A which varies little with composition and not at all with density

Definitions:
sigma(barns/atom)=C*sigma(cm^2/gm)
x=distance from the current impact point to the origin (cm)
(which is opposite the target)
r=distance from the current impact point direct to the target (cm)
theta= angle between r and x

ALS 1.9 GeV
Ecrit=12 keV
I=0.4 Amp

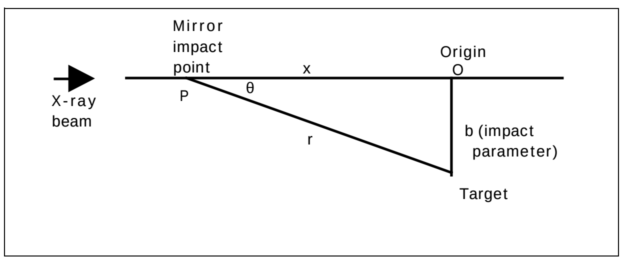
Calculation of scatttered energy

E (keV) incident	E' (keV) at x, r, theta (see H23:H25)	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->
10	9.99E+00	9.99E+00	9.99E+00	9.98E+00	9.98E+00	9.97E+00	9.96E+00	9.94E+00	9.91E+00	9.87E+00	9.81E+00
15	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.49E+01	1.49E+01	1.49E+01	1.48E+01	1.47E+01	1.46E+01
20	2.00E+01	2.00E+01	2.00E+01	1.99E+01	1.99E+01	1.99E+01	1.98E+01	1.98E+01	1.97E+01	1.95E+01	1.92E+01
30	2.99E+01	2.99E+01	2.99E+01	2.99E+01	2.98E+01	2.98E+01	2.97E+01	2.95E+01	2.92E+01	2.88E+01	2.83E+01
40	3.99E+01	3.98E+01	3.98E+01	3.97E+01	3.97E+01	3.96E+01	3.94E+01	3.91E+01	3.87E+01	3.80E+01	3.71E+01
50	4.98E+01	4.98E+01	4.97E+01	4.96E+01	4.95E+01	4.93E+01	4.90E+01	4.86E+01	4.79E+01	4.69E+01	4.55E+01
60	5.97E+01	5.96E+01	5.96E+01	5.94E+01	5.93E+01	5.90E+01	5.86E+01	5.80E+01	5.70E+01	5.55E+01	5.37E+01
80	7.95E+01	7.94E+01	7.92E+01	7.90E+01	7.87E+01	7.83E+01	7.76E+01	7.65E+01	7.48E+01	7.23E+01	6.92E+01
100	9.92E+01	9.90E+01	9.88E+01	9.84E+01	9.80E+01	9.73E+01	9.62E+01	9.46E+01	9.20E+01	8.82E+01	8.36E+01
150	1.48E+02	1.48E+02	1.47E+02	1.47E+02	1.45E+02	1.44E+02	1.42E+02	1.38E+02	1.33E+02	1.25E+02	1.16E+02
200	1.97E+02	1.96E+02	1.95E+02	1.94E+02	1.92E+02	1.89E+02	1.85E+02	1.79E+02	1.70E+02	1.58E+02	1.44E+02
300	2.93E+02	2.91E+02	2.89E+02	2.86E+02	2.82E+02	2.77E+02	2.68E+02	2.56E+02	2.38E+02	2.14E+02	1.89E+02
400	3.87E+02	3.85E+02	3.81E+02	3.76E+02	3.69E+02	3.60E+02	3.46E+02	3.25E+02	2.97E+02	2.61E+02	2.24E+02
500	4.80E+02	4.76E+02	4.71E+02	4.63E+02	4.53E+02	4.39E+02	4.18E+02	3.89E+02	3.48E+02	3.00E+02	2.53E+02
600	5.72E+02	5.66E+02	5.58E+02	5.48E+02	5.34E+02	5.14E+02	4.86E+02	4.46E+02	3.94E+02	3.33E+02	2.76E+02
800	7.50E+02	7.41E+02	7.27E+02	7.10E+02	6.87E+02	6.54E+02	6.09E+02	5.48E+02	4.71E+02	3.86E+02	3.12E+02
1000	9.24E+02	9.09E+02	8.89E+02	8.63E+02	8.29E+02	7.82E+02	7.19E+02	6.36E+02	5.34E+02	4.28E+02	3.38E+02

x=-->	1.00E+01	9.00E+00	8.00E+00	7.00E+00	6.00E+00	5.00E+00	4.00E+00	3.00E+00	2.00E+00	1.00E+00	0.00E+00
r=-->	1.04E+01	9.49E+00	8.54E+00	7.62E+00	6.71E+00	5.83E+00	5.00E+00	4.24E+00	3.61E+00	3.16E+00	3.00E+00
cos(theta)=-->	9.58E-01	9.49E-01	9.36E-01	9.19E-01	8.94E-01	8.57E-01	8.00E-01	7.07E-01	5.55E-01	3.16E-01	0.00E+00

E(keV)	Iron Incoherent xsect cm^2/gm	Iron Total xsect cm^2/gm	Flux/unit solid angle (ph/s/mr^2/0.1%BW)	ph/s/cm of mir length/ actual BW (meaning the interval to the previous energy)	Compton portion (same units)
10	0.1088	34.43	2.825E+13		
15	0.129	10.27	2.626E+13	1.818E+14	2.284E+12
20	0.1404	4.363	2.225E+13	1.155E+14	3.717E+12
30	0.1808	1.383	1.390E+13	9.620E+13	1.258E+13
40	0.154	0.6656	7.858E+12	4.080E+13	9.440E+12
50	0.1542	0.4258	4.202E+12	1.745E+13	6.321E+12
60	0.153	0.3143	2.167E+12	7.501E+12	3.651E+12
80	0.1485	0.2205	5.377E+11	2.792E+12	1.880E+12
100	0.1433	0.1828	1.258E+11	5.224E+11	4.095E+11
150	0.1309	0.1449	2.887E+09	1.998E+10	1.805E+10
200	0.1207	0.1277	5.926E+07	3.077E+08	2.908E+08
300	0.1055	0.1082	2.121E+04	1.468E+05	1.432E+05
400	0.0947	0.09614	6.960E+00	3.614E+01	3.560E+01
500	0.08659	0.08746	2.198E-03	9.132E-03	9.041E-03
600	0.08013	0.08072	6.822E-07	2.361E-06	2.344E-06
800	0.07044	0.07076	6.293E-14	3.267E-13	3.253E-13
1000	0.06334	0.06354	5.466E-21	2.271E-20	2.263E-20

	Flux on target (p/s/actual BW)	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->
15	0.00E+00	0.00E+00	1.15E-288	3.10E-256	1.62E-224	7.53E-194	8.59E-165	2.63E-138	4.93E-116	1.47E-100	6.50E-95
20	1.75E-99	1.70E-89	1.30E-79	7.12E-70	2.41E-60	4.01E-51	2.21E-42	2.06E-34	1.02E-27	4.40E-23	2.08E-21
30	1.17E-36	2.27E-32	4.00E-28	6.19E-24	7.88E-20	7.45E-16	4.42E-12	1.22E-08	9.32E-06	8.87E-04	4.43E-03
40	3.12E-05	8.06E-04	2.04E-02	5.01E-01	1.17E+01	2.49E+02	4.60E+03	6.57E+04	5.97E+05	2.59E+06	4.12E+06
50	7.89E+02	4.14E+03	2.17E+04	1.13E+05	5.75E+05	2.83E+06	1.30E+07	5.20E+07	1.61E+08	3.29E+08	3.95E+08
60	1.56E+05	4.82E+05	1.49E+06	4.60E+06	1.41E+07	4.25E+07	1.22E+08	3.18E+08	6.88E+08	1.08E+09	1.17E+09
80	1.24E+06	2.99E+06	7.22E+06	1.75E+07	4.23E+07	1.01E+08	2.32E+08	4.92E+08	8.88E+08	1.22E+09	1.23E+09
100	2.74E+06	5.33E+06	1.05E+07	2.07E+07	4.08E+07	8.01E+07	1.53E+08	2.72E+08	4.21E+08	5.14E+08	4.89E+08
150	3.27E+05	5.84E+05	1.05E+06	1.90E+06	3.45E+06	6.20E+06	1.08E+07	1.76E+07	2.49E+07	2.80E+07	2.51E+07
200	1.42E+04	2.32E+04	3.83E+04	6.36E+04	1.06E+05	1.74E+05	2.79E+05	4.16E+05	5.39E+05	5.61E+05	3.66E+05
300	1.18E+01	1.86E+01	2.93E+01	4.65E+01	7.36E+01	1.15E+02	1.73E+02	2.41E+02	2.89E+02	2.79E+02	1.99E+02
400	5.15E-03	7.69E-03	1.16E-02	1.74E-02	2.61E-02	3.85E-02	5.46E-02	7.09E-02	6.72E-02	6.22E-02	4.84E-02
500	1.87E-06	2.71E-06	3.94E-06	5.74E-06	8.29E-06	1.17E-05	1.59E-05	1.74E-05	1.88E-05	1.43E-05	1.09E-05
600	6.33E-10	8.95E-10	1.27E-09	1.80E-09	2.52E-09	3.46E-09	4.07E-09	4.90E-09	4.55E-09	3.91E-09	2.52E-09
800	1.12E-16	1.55E-16	2.14E-16	2.95E-16	3.99E-16	5.25E-16	6.51E-16	6.83E-16	6.16E-16	4.62E-16	3.32E-16
1000	1.06E-23	1.42E-23	1.90E-23	2.51E-23	3.27E-23	3.59E-23	4.32E-23	4.68E-23	4.11E-23	3.06E-23	1.97E-23



	Dose in rad/sec	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->
10	0.00E+00	0.00E+00	1.42E-300	3.83E-268	2.00E-236	9.29E-206	1.06E-176	3.22E-150	5.98E-128	1.76E-112	0
15	3.71E-111	3.61E-101	2.75E-91	1.50E-81	5.09E-72	8.43E-63	4.63E-54	4.29E-46	2.10E-39	8.90E-35	1.2873E-106
20	5.16E-48	1.00E-43	1.77E-39	2.72E-35	3.46E-31	3.26E-27	1.92E-23	5.25E-20	3.95E-17	3.67E-15	8.34698E-33
30	2.28E-16	5.89E-15	1.49E-13	3.64E-12	8.46E-11	1.80E-09	3.29E-08	4.65E-07	4.14E-06	1.74E-05	2.8592E-14
40	8.42E-09	4.41E-08	2.31E-07	1.19E-06	6.07E-06	2.97E-05	1.35E-04	5.32E-04	1.62E-03	3.17E-03	3.78643E-05
50	2.26E-06	6.94E-06	2.14E-05	6.58E-05	2.01E-04	6.00E-04	1.71E-03	4.38E-03	9.19E-03	1.39E-02	0.004777124
60	2.83E-05	6.78E-05	1.63E-04	3.94E-04	9.47E-04	2.24E-03	5.08E-03	1.06E-02	1.84E-02	2.39E-02	0.021365208
80	8.73E-05	1.70E-04	3.32E-04	6.51E-04	1.28E-03	2.48E-03	4.65E-03	8.08E-03	1.20E-02	1.37E-02	0.030277263
100	1.85E-05	3.29E-05	5.90E-05	1.06E-04	1.90E-04	3.37E-04	5.76E-04	9.06E-04	1.21E-03	1.25E-03	0.019614928
150	1.17E-06	1.90E-06	3.13E-06	5.14E-06	8.45E-06	1.37E-05	2.13E-05	3.04E-05	3.68E-05	3.46E-05	0.001361748
200	1.58E-09	2.47E-09	3.87E-09	6.06E-09	9.44E-09	1.44E-08	2.09E-08	2.75E-08	3.02E-08	2.56E-08	2.86783E-05
300	9.40E-13	1.40E-12	2.08E-12	3.08E-12	4.54E-12	6.50E-12	8.81E-12	1.07E-11	9.12E-12	7.25E-12	1.93223E-08
400	4.28E-16	6.15E-16	8.84E-16	1.27E-15	1.79E-15	2.45E-15	3.15E-15	3.20E-15	3.05E-15	1.96E-15	5.43561E-12
500	1.72E-19	2.41E-19	3.37E-19	4.69E-19	6.42E-19	8.47E-19	9.43E-19	1.04E-18	8.47E-19	6.05E-19	1.35446E-15
600	3.94E-26	5.37E-26	7.30E-26	9.82E-26	1.29E-25	1.62E-25	1.88E-25	1.78E-25	1.38E-25	8.42E-26	3.62738E-19
800	4.45E-33	5.87E-33	7.70E-33	9.96E-33	1.25E-32	1.31E-32	1.46E-32	1.41E-32	1.05E-32	6.22E-33	5.23592E-26
1000											
Total dose all energies (rad) due to arriving x-rays at x ------------------>	1.37E-04	2.79E-04	5.79E-04	1.22E-03	2.63E-03	5.70E-03	1.22E-02	2.45E-02	4.24E-02	5.59E-02	7.75E-02

Total dose all energies and arrival points (rads/sec)	2.23E-01
Time for allowed dose (years)	7.11E+01

COMPTON SCATTERING CALCULATION
M. Howells, 7-1-99

Incoherent and total cross sections from McMaster

Source mirror distance (m)	6.5	
Grazing angle (rad)	0.0045	
Beam width (cm)	1	
mr H	3	
mrV (to illuminate 1 cm of mir)	0.006923077	(calculated)
Impact parameter (cm)	0.3	
Target size (cm)	1	(do not change)
Conversion factor C (Si)	46.63	
Thompson sigma (barns/e-)	0.6652	
Atomic number (Si)	14	
Electron rest mass (keV)	511	
Thickness (cm)	1	
Density W (g/cc)	19.3	
Density Si (g/cc)	2.33	
Target atomic number	7	
Target atomic weight	14.007	
Allowed dose (rad)	5.000E+08	

Note: input data yellow
independent variables blue

Note: The Compton dose depends only on the number of electrons per unit mass of the target - ie on Z/A which varies little with composition and not at all with density

Definitions:
sigma(barns/atom)=C*sigma(cm^2/gm)
x=distance from the current impact point to the origin (cm)
(which is opposite the target)
r=distance from the current impact point direct to the target (cm)
theta= angle between r and x

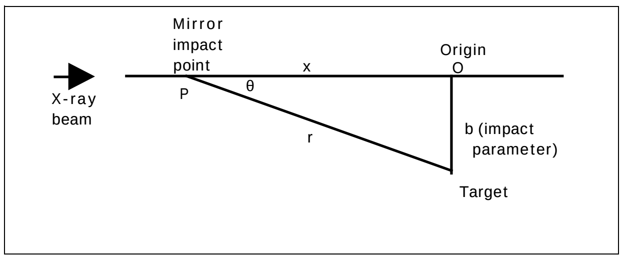
ALS 1.9 GeV
Ecrit=12 keV
I=0.4 Amp

E (keV) incident	E' (keV) at x, r, theta (see H23:H25)	-------->	-------->	-------->	Calculation of scatttered energy		-------->	-------->	-------->	-------->	-------->
		-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->
10	1.00E+01	1.00E+01	1.00E+01	1.00E+01	1.00E+01	1.00E+01	1.00E+01	1.00E+01	1.00E+01	9.99E+00	9.81E+00
15	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.46E+01
20	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	1.92E+01
30	3.00E+01	3.00E+01	3.00E+01	3.00E+01	3.00E+01	3.00E+01	3.00E+01	3.00E+01	3.00E+01	2.99E+01	2.83E+01
40	4.00E+01	4.00E+01	4.00E+01	4.00E+01	4.00E+01	4.00E+01	4.00E+01	4.00E+01	4.00E+01	3.99E+01	3.71E+01
50	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	4.99E+01	4.98E+01	4.55E+01
60	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	5.99E+01	5.97E+01	5.37E+01
80	8.00E+01	8.00E+01	8.00E+01	8.00E+01	8.00E+01	8.00E+01	8.00E+01	7.99E+01	7.99E+01	7.95E+01	6.92E+01
100	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	9.99E+01	9.99E+01	9.98E+01	9.92E+01	8.36E+01
150	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.48E+02	1.16E+02
200	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	1.99E+02	1.97E+02	1.44E+02
300	3.00E+02	3.00E+02	3.00E+02	3.00E+02	3.00E+02	3.00E+02	3.00E+02	2.99E+02	2.98E+02	2.93E+02	1.89E+02
400	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	3.99E+02	3.99E+02	3.98E+02	3.97E+02	3.87E+02	2.24E+02
500	5.00E+02	5.00E+02	5.00E+02	5.00E+02	4.99E+02	4.99E+02	4.99E+02	4.98E+02	4.95E+02	4.80E+02	2.53E+02
600	6.00E+02	6.00E+02	6.00E+02	5.99E+02	5.99E+02	5.99E+02	5.98E+02	5.97E+02	5.92E+02	5.72E+02	2.76E+02
800	7.99E+02	7.99E+02	7.99E+02	7.99E+02	7.98E+02	7.98E+02	7.97E+02	7.94E+02	7.86E+02	7.50E+02	3.12E+02
1000	9.99E+02	9.99E+02	9.99E+02	9.98E+02	9.98E+02	9.96E+02	9.95E+02	9.90E+02	9.79E+02	9.24E+02	3.38E+02

x=-->	1.00E+01	9.00E+00	8.00E+00	7.00E+00	6.00E+00	5.00E+00	4.00E+00	3.00E+00	2.00E+00	1.00E+00	0.00E+00
r=-->	1.00E+01	9.00E+00	8.01E+00	7.01E+00	6.01E+00	5.01E+00	4.01E+00	3.01E+00	2.02E+00	1.04E+00	3.00E-01
cos(theta)=-->	1.00E+00	9.99E-01	9.99E-01	9.99E-01	9.99E-01	9.98E-01	9.97E-01	9.95E-01	9.89E-01	9.58E-01	0.00E+00

E(keV)	Iron Incoherent xsect cm^2/gm	Iron Total xsect cm^2/gm	Flux/unit solid angle (ph/s/mr^2/0.1%BW)	ph/s/cm of mir length/ actual BW (meaning the interval to the previous energy)	Compton portion (same units)
10	0.1088	34.43	2.825E+13		
15	0.129	10.27	2.626E+13	1.818E+14	2.284E+12
20	0.1404	4.363	2.225E+13	1.155E+14	3.717E+12
30	0.1808	1.383	1.390E+13	9.620E+13	1.258E+13
40	0.154	0.6656	7.858E+12	4.080E+13	9.440E+12
50	0.1542	0.4258	4.202E+12	1.745E+13	6.321E+12
60	0.153	0.3143	2.167E+12	7.501E+12	3.651E+12
80	0.1485	0.2205	5.377E+11	2.792E+12	1.880E+12
100	0.1433	0.1828	1.258E+11	5.224E+11	4.095E+11
150	0.1309	0.1449	2.887E+09	1.998E+10	1.805E+10
200	0.1207	0.1277	5.926E+07	3.077E+08	2.908E+08
300	0.1055	0.1082	2.121E+04	1.468E+05	1.432E+05
400	0.0947	0.09614	6.960E+00	3.614E+01	3.560E+01
500	0.08659	0.08746	2.198E-03	9.132E-03	9.041E-03
600	0.08013	0.08072	6.822E-07	2.361E-06	2.344E-06
800	0.07044	0.07076	6.293E-14	3.267E-13	3.253E-13
1000	0.06334	0.06354	5.466E-21	2.271E-20	2.263E-20

	Flux on target (p/s/actual BW)	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->
		-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->
15	0.00E+00	0.00E+00	8.00E-270	6.77E-235	5.84E-200	5.15E-165	4.64E-130	4.20E-95	3.54E-60	1.56E-25	7.60E+01
20	6.76E-95	2.03E-84	6.26E-74	1.98E-63	6.47E-53	2.21E-42	8.06E-32	3.21E-21	1.47E-10	7.81E+00	2.39E+09
30	1.12E-34	3.58E-30	1.17E-25	3.94E-21	1.38E-16	5.07E-12	2.01E-07	8.86E-03	4.72E+02	3.56E+07	3.69E+11
40	1.46E-04	4.50E-03	1.43E-01	4.66E+00	1.58E+02	5.68E+03	2.20E+05	9.64E+06	5.21E+08	4.40E+10	2.48E+12
50	1.78E+03	1.04E+04	6.18E+04	3.80E+05	2.43E+06	1.64E+07	1.20E+08	9.95E+08	1.02E+10	1.68E+11	2.60E+12
60	2.78E+05	9.24E+05	3.15E+06	1.11E+07	4.06E+07	1.57E+08	6.58E+08	3.12E+09	1.84E+10	1.75E+11	1.70E+12
80	1.98E+06	5.09E+06	1.34E+07	3.63E+07	1.03E+08	3.06E+08	9.90E+08	3.62E+09	1.65E+10	1.21E+11	8.89E+11
100	3.98E+06	8.22E+06	1.74E+07	3.79E+07	8.60E+07	2.07E+08	5.37E+08	1.58E+09	5.79E+09	3.42E+10	1.96E+11
150	4.63E+05	8.75E+05	1.69E+06	3.38E+06	7.04E+06	1.55E+07	3.68E+07	9.92E+07	3.33E+08	1.79E+09	7.92E+09
200	1.96E+04	3.38E+04	6.00E+04	1.10E+05	2.09E+05	4.20E+05	9.16E+05	2.26E+06	6.93E+06	3.38E+07	1.16E+08
300	1.65E+01	2.73E+01	4.65E+01	8.17E+01	1.50E+02	2.89E+02	6.05E+02	1.43E+03	4.20E+03	1.94E+04	4.95E+04
400	7.18E-03	1.14E-02	1.85E-02	3.11E-02	5.44E-02	1.00E-01	2.01E-01	4.53E-01	1.27E+00	5.50E+00	1.08E+01
500	2.64E-06	4.07E-06	6.45E-06	1.05E-05	1.79E-05	3.21E-05	6.23E-05	1.37E-04	3.70E-04	1.54E-03	2.42E-03
600	9.05E-10	1.37E-09	2.12E-09	3.39E-09	5.65E-09	9.94E-09	1.89E-08	4.06E-08	1.07E-07	4.29E-07	5.63E-07
800	1.67E-16	2.49E-16	3.80E-16	5.97E-16	9.78E-16	1.69E-15	3.17E-15	6.68E-15	1.73E-14	6.58E-14	6.57E-14
1000	1.63E-23	2.37E-23	3.53E-23	5.43E-23	8.69E-23	1.47E-22	2.68E-22	5.51E-22	1.38E-21	4.99E-21	3.90E-21



	Dose in rad/sec	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->
		-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->	-------->
10	0.00E+00	0.00E+00	9.95E-282	8.42E-247	7.27E-212	6.41E-177	5.77E-142	5.22E-107	4.40E-72	1.94E-37	0
15	1.44E-106	4.33E-96	1.33E-85	4.20E-75	1.37E-64	4.70E-54	1.71E-43	6.83E-33	3.11E-22	1.65E-11	1.50481E-10
20	4.98E-46	1.59E-41	5.19E-37	1.75E-32	6.11E-28	2.25E-23	8.90E-19	3.93E-14	2.09E-09	1.57E-04	0.009564771
30	1.07E-15	3.31E-14	1.05E-12	3.42E-11	1.16E-09	4.17E-08	1.62E-06	7.08E-05	3.82E-03	3.22E-01	2.380130718
40	1.92E-08	1.11E-07	6.64E-07	4.08E-06	2.61E-05	1.77E-04	1.29E-03	1.07E-02	1.10E-01	1.79E+00	22.73992602
50	4.04E-06	1.34E-05	4.58E-05	1.61E-04	5.90E-04	2.28E-03	9.56E-03	4.53E-02	2.67E-01	2.52E+00	31.45453406
60	4.55E-05	1.17E-04	3.07E-04	8.34E-04	2.36E-03	7.03E-03	2.27E-02	8.32E-02	3.78E-01	2.76E+00	31.12111523
80	1.29E-04	2.65E-04	5.60E-04	1.22E-03	2.77E-03	6.66E-03	1.73E-02	5.09E-02	1.86E-01	1.09E+00	21.86906873
100	2.66E-05	5.03E-05	9.74E-05	1.95E-04	4.05E-04	8.90E-04	2.12E-03	5.70E-03	1.91E-02	1.01E-01	7.852808912
150	1.65E-06	2.85E-06	5.04E-06	9.22E-06	1.76E-05	3.53E-05	7.70E-05	1.90E-04	5.80E-04	2.79E-03	0.430064105
200	2.26E-09	3.76E-09	6.40E-09	1.12E-08	2.05E-08	3.97E-08	8.30E-08	1.96E-07	5.74E-07	2.59E-06	0.00905712
300	1.36E-12	2.15E-12	3.50E-12	5.88E-12	1.03E-11	1.90E-11	3.79E-11	8.54E-11	2.38E-10	1.00E-09	4.8078E-06
400	6.29E-16	9.70E-16	1.53E-15	2.50E-15	4.25E-15	7.63E-15	1.48E-14	3.24E-14	8.73E-14	3.51E-13	1.21379E-09
500	2.58E-19	3.90E-19	6.04E-19	9.66E-19	1.61E-18	2.82E-18	5.37E-18	1.15E-17	3.02E-17	1.17E-16	3.02456E-13
600	6.19E-26	9.22E-26	1.41E-25	2.21E-25	3.62E-25	6.26E-25	1.17E-24	2.46E-24	6.31E-24	2.31E-23	8.10006E-17
800	7.31E-33	1.06E-32	1.58E-32	2.43E-32	3.89E-32	6.57E-32	1.20E-31	2.45E-31	6.10E-31	2.09E-30	1.03422E-23
1000											
Total dose all energies (rad) due to arriving x-rays at x ------------------>	2.06E-04	4.49E-04	1.02E-03	2.42E-03	6.17E-03	1.71E-02	5.31E-02	1.96E-01	9.65E-01	8.59E+00	1.18E+02

Total dose all energies and arrival points (rads/sec) 1.28E+02

Time for allowed dose (years) 1.24E-01