Theoretical Notes

Note 175

12 December 1972

Preliminary Curve-fit Representations for Gamma Induced Air-over-ground EMP Sources

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Abstract

Curve-fit representations of EMP sources in the air near an air-ground interface are given for eight monoenergetic gamma ray energies for the case of the gamma source on the ground. Example overlay plots of curve-fits and data are given and an example computer program which uses the curve-fits is listed.

I. Introduction

Monte Carlo gamma ray transport calculations of air-over-ground gamma induced EMP sources were performed by the Dikewood Corporation. The EMP sources were calculated for eight monoenergetic gamma ray energies (1 Mev through 8 Mev) at three different gamma ray source altitudes (0,200 and 500 meters). The time history of the gamma ray source was a delta function and only the EMP sources created by scattered gamma rays were scored. The geometries used in the calculation were a spherical (R,θ) geometry above the source and a cylindrical (R,Z) geometry below the source. The bin structure used to score the results were 50 meter range bins to a range of 3000 meters, 10 angle bins above the source, 0.025 meter depth bins in the ground to a depth of 0.5 meters, and 50 meter altitude bins between the ground and the source altitude. Twenty logarithmically varying time bins were used for the local time span of 0-100 shakes. The air density used in the calculations was 1.29 mg/cc and the ground density was 2.35 g/cc.

At the present time the only gamma induced EMP sources which have been curve-fit are those for the case of the angular bin in the air which is closest to the air-ground interface with the gamma ray source on the ground. Only the EMP sources created by scattered gamma rays have been curve-fit. For this one case the EMP sources have been curve-fit for all eight gamma ray energies. The geometry for the present curve-fits is shown in Figure 1. The curve-fits given in this report are for the line-of-sight shown by a dashed line in Figure 1. The theta angle between vertical and the line-of-sight is 87.13° (cosine $\theta = 0.05$). J_R and J_θ are the two components of the electron current.

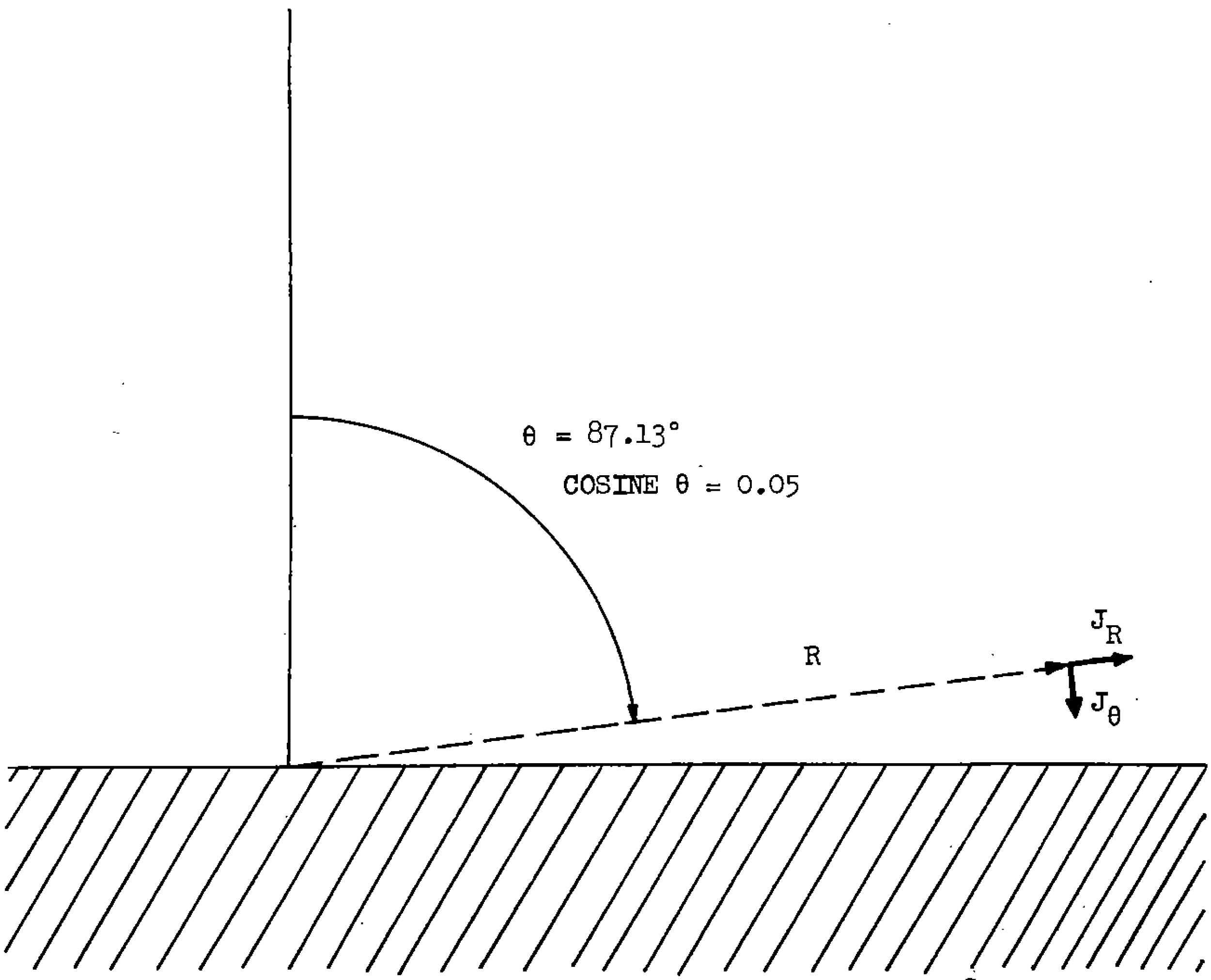


Figure 1.
Geometry for the EMP sources
which have been curve-fit

II. Curve-fit Method

The least squares method was used to curve-fit the EMP sources. More accurately stated the natural logarithms of the data were curve-fit to the natural logarithm of the curve-fit function. The data was first curve-fit in time at each range. Then at three separate times (0,10, and 70 shakes) the time curve-fit values were fit in range. The same curve-fit functions were used to fit the ionization rate, the radial electron current, and the theta electron current. The reciprocal of the statistics of the Monte Carlo data was used as the data weight factors in the curve-fit procedure. If the statistics on any data point was greater than 100%, the point was not used.

III. Units

The following units are used on all curve-fits in this report:

Local time (t)	shakes (10^{-8} seconds)
Range (R)	meters
Ionization rate (Q)	$\frac{\text{Mev}}{\text{meter}^3\text{-second-source photon}}$
Radial electron current (J_R)	$\frac{\text{electrons}}{\text{meter}^2\text{-second-source photon}}$
Theta electron current (J_θ)	$\frac{\text{electrons}}{\text{meter}^2\text{-second-source photon}}$

IV. How to Use Curve-Fits

There are nine curve-fit constants for each EMP source for each of the eight gamma ray energies. Since the same curve-fit functions were used for all three EMP sources, let F represent any one of the three. Then at any range R

$$F(t = 0) = a_1 e^{a_4 R} R^{a_7} \quad (1)$$

$$F(t = 10) = a_2 e^{a_5 R} R^{a_8} \quad (2)$$

$$F(t = 70) = a_3 e^{a_6 R} R^{a_9} \quad (3)$$

where a_1 through a_9 are the curve fit constants in the order given in the computer code data statement listed on page 22. More explanation concerning the order of the constants in the data statement will be given at the end of this section. These three values of F now can be used to determine the curve-fit parameters in the time domain at the given range.

$$A = F(t = 0) \quad (4)$$

$$B = D \left[\ln \frac{F(t = 10)}{A} \ln(71) - \ln \frac{F(t = 70)}{A} \ln(11) \right] \quad (5)$$

$$C = D \left[10 \ln \frac{F(t = 70)}{A} - 70 \ln \frac{F(t = 10)}{A} \right] \quad (6)$$

where $D = 1/ [10 \ln(71) - 70 \ln (11)]$ (7)

Now the curve-fit function in the time domain can be used to calculate the EMP source at any time

$$F(t,R) = Ae^{Bt} (t + 1)^C \quad (8)$$

Using the curve-fits in a computer source code is very easy when one has the data statements which give the curve-fit constants and subroutine ABC. These are included in the listing of the example program starting on page 22. Anyone wanting a card deck copy of this example program can obtain one by writing to the author.

There are nine curve-fit constants for each of the eight monoenergetic gamma ray energies and each of the three EMP sources. The dimension statement needed in the program for the curve-fit constants is the following:

```
DIMENSION QTFT(9,8),RTFT (9,8),TTFT(9,8)
```

QTFT, RTFT, and TTFT are the curve-fit constant arrays for the ionization rate, radial electron current, and theta electron current respectively. Within each data statement the constants are in the following order: a_1 through a_9 for 1 Mev, a_1 through a_9 for 2 Mev, and so forth through 8 Mev.

To obtain the time domain curve-fit constants (A,B,C) at any range for any of the three EMP sources, simply call subroutine ABC with the range and the first word location of the appropriate range fit constants.

```
CALL ABC (R, TTFT(1,IE), A,B,C)
```

where R = range in meters (floating point number)

TTFT(1,IE) = range fit constants for the theta electron current for gamma ray energy IE.

IE = monoenergetic gamma ray energy (fixed point number)

For example, to obtain the time domain curve-fit constants for the radial electron current for a 3 Mev gamma ray at a range of 1125 meters, call subroutine ABC as follows:

```
CALL ABC(1125.,RTFT (1,3), A,B,C)
```

Now the time fit constants can be used to calculate the EMP source at any time T in shakes.

```
F = A*EXP(B*T)*(T+1.)**C
```

V. Results and Discussion

Example overlays of curve-fits and data are given in Figures 2 through 13. Figures 2-5 show the ionization rate at ranges of 525, 825, 1125, and 1425 meters respectively. Figures 6-9 show radial electron currents and Figures 10-13 show theta electron currents at the same ranges. All of these figures are of EMP sources from a 2 Mev gamma ray. The tick marks on the data points represent the statistics of the Monte Carlo data. A data point was not plotted if the statistics on the data point was greater than 100%.

Figures 2-13 are also typical of overlay plots for EMP sources created by the other seven gamma ray energies. One can see from these plots that the curve-fits of ionization rate and radial electron current are adequate for EMP field calculations. The curve-fits of theta electron current for times less than one or two shakes are less satisfactory mainly because of the poor Monte Carlo data at these times. The present curve-fits overestimate the theta electron currents at these early times. If it can be determined that the theta electron current curve-fits are not adequate for EMP field calculations, then better Monte Carlo data and a different curve-fit function will be needed to represent these currents at early times.

A small warning should be given about the times and ranges over which the curve-fits are usable. The curve-fits are usable for all ranges greater than 100 meters and for all times less than 70 shakes. These limitations should not affect most EMP field calculations, but the user should be aware of these limitations if he tries to use the curve-fits for some other purpose.

On pages 22-24 is a listing of an example computer program which uses the curve-fit constants. The user merely puts the desired range in the code (page 23) and the code will output examples of the EMP sources at 21 different times for all eight monoenergetic gamma energies. On pages 25-27 is an example output at a range of 1000 meters and on pages 28-30 is an example output at a range of 3000 meters. One important point to note on the example output at 3000 meters is that the EMP sources from 8 Mev gamma rays are factors of 10^5 to 10^6 larger than EMP sources from 1 Mev gammas. Therefore, even a comparatively small number of high energy gamma rays in a gamma spectrum can be a very important contributor to the EMP sources at far ranges.

The author plans to complete the curve-fitting of EMP sources for the case of the gamma source on the ground by first fitting the angular variation in the air, and then the sources in the ground. Curve-fits for the off-the-ground cases will be done later.

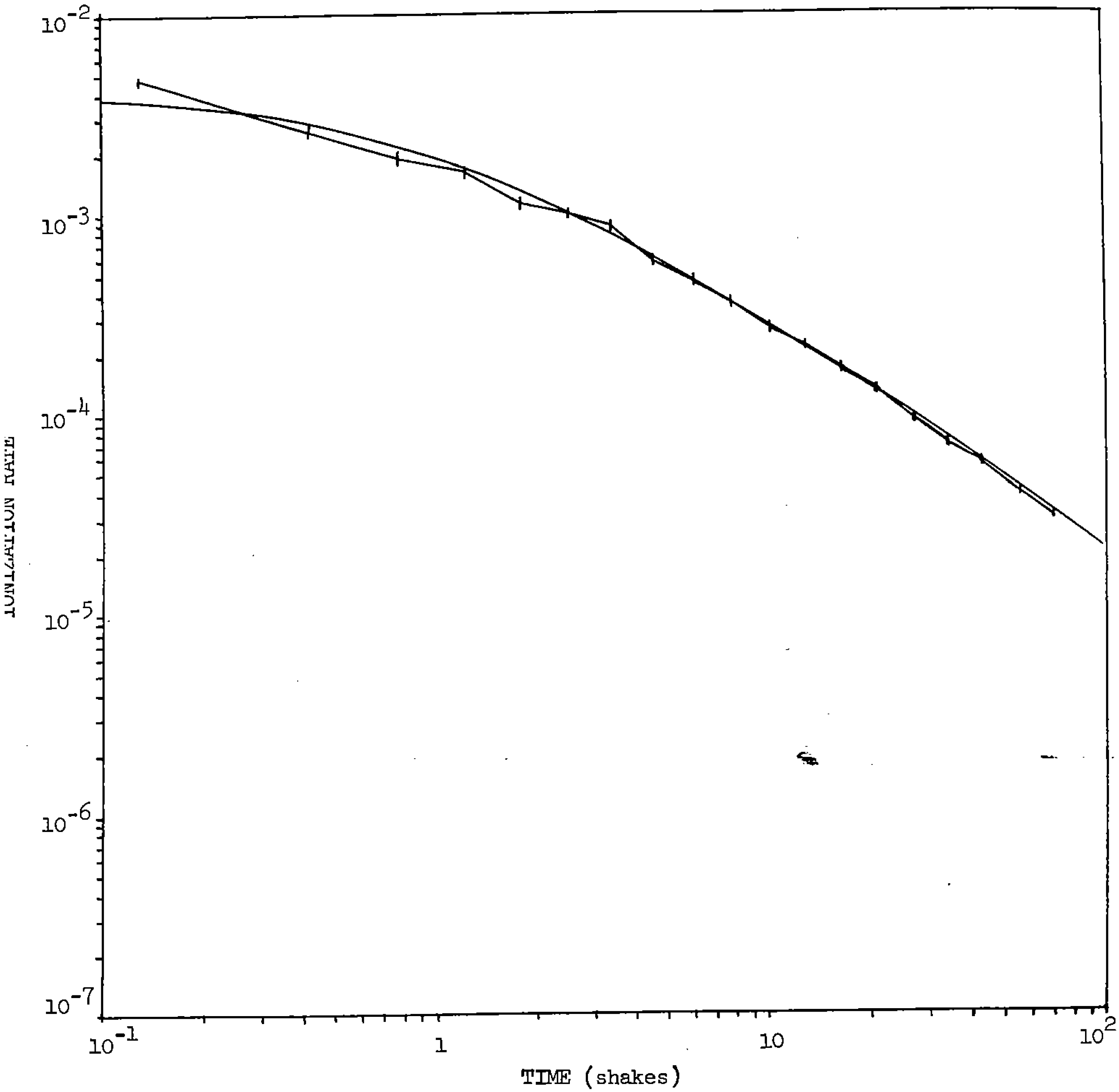


Figure 2.
[illegible] sus time at a range
of 525 meters; gamma ray energy = 2 Mev

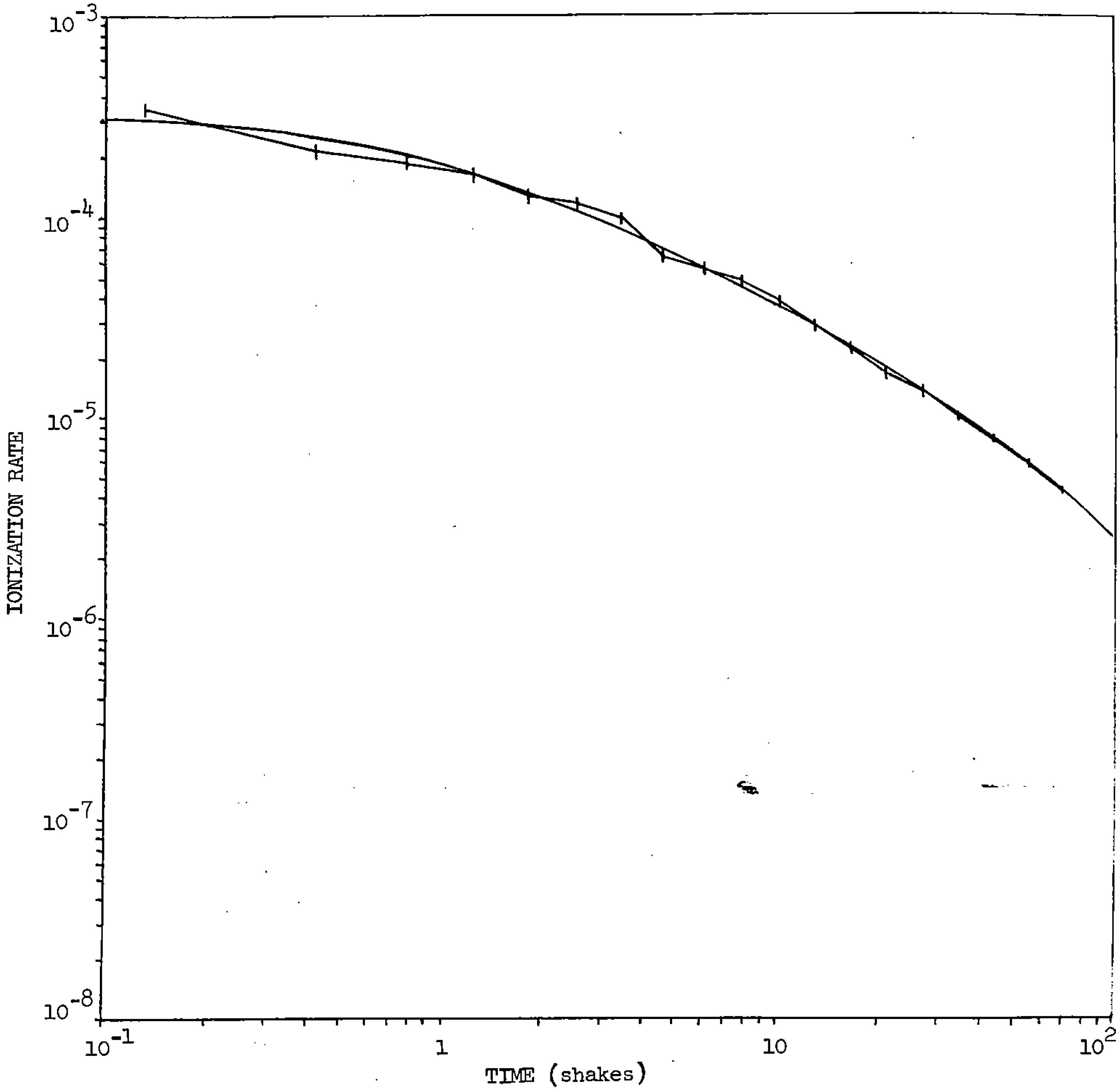


Figure 3.
Ionization rate versus time at a range of 825 meters, gamma ray energy = 2 Mev.

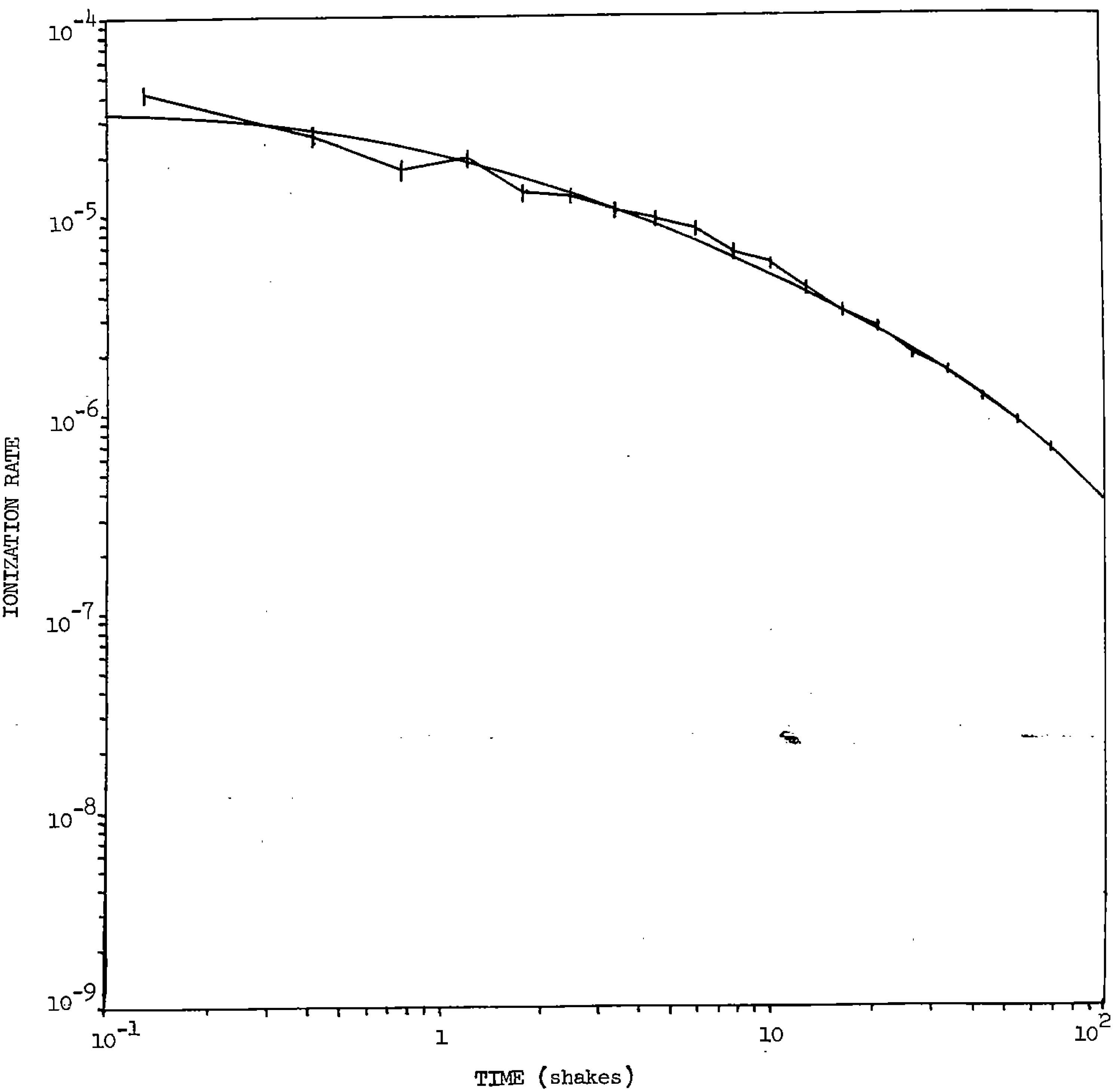


Figure [illegible]
Ionization rate versus time at a range
of 1125 meters; gamma ray energy = 2 Mev

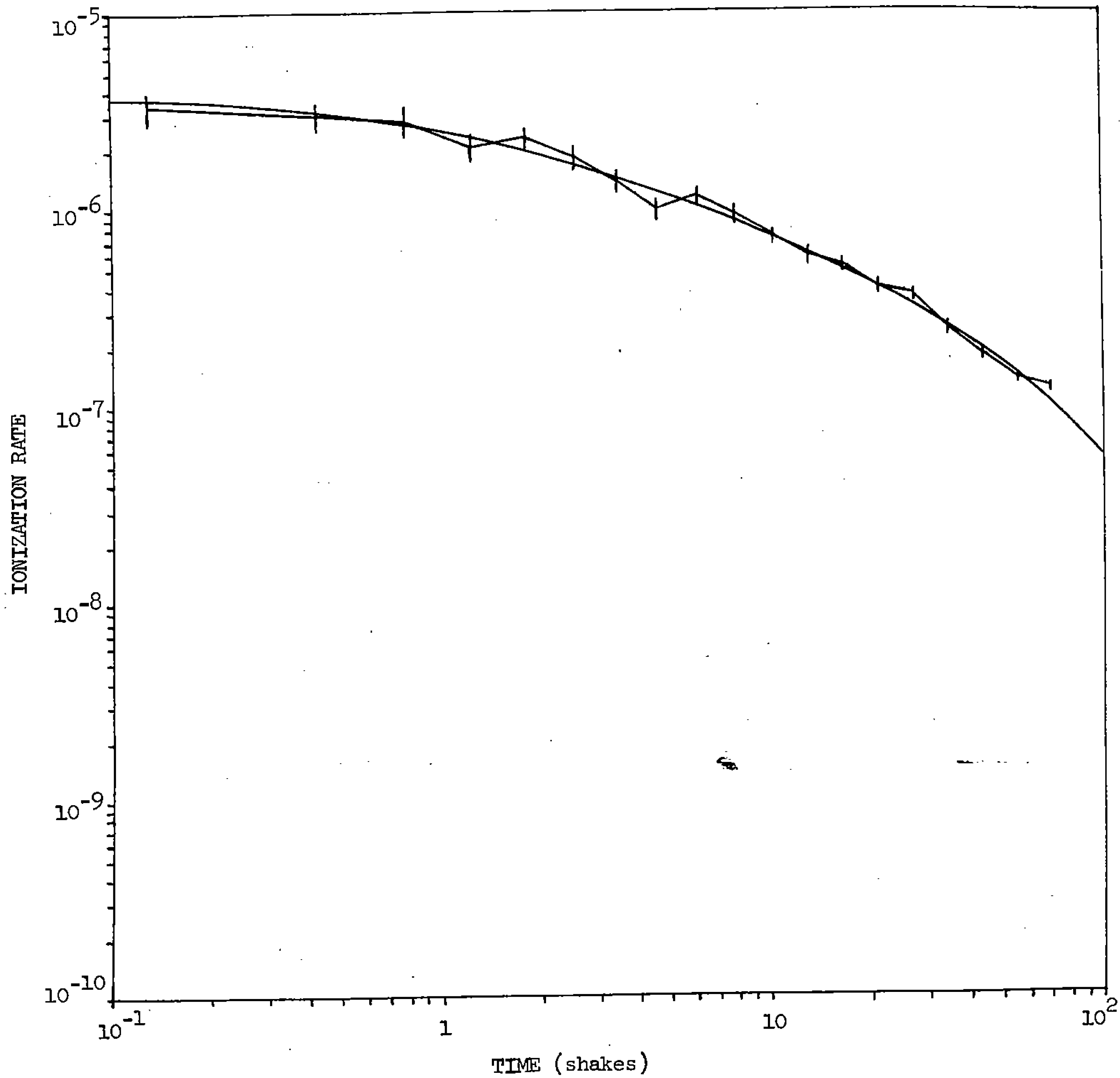


Figure 5.
Ionization rate versus time at a range of 1425 meters; gamma ray energy = 2 Mev

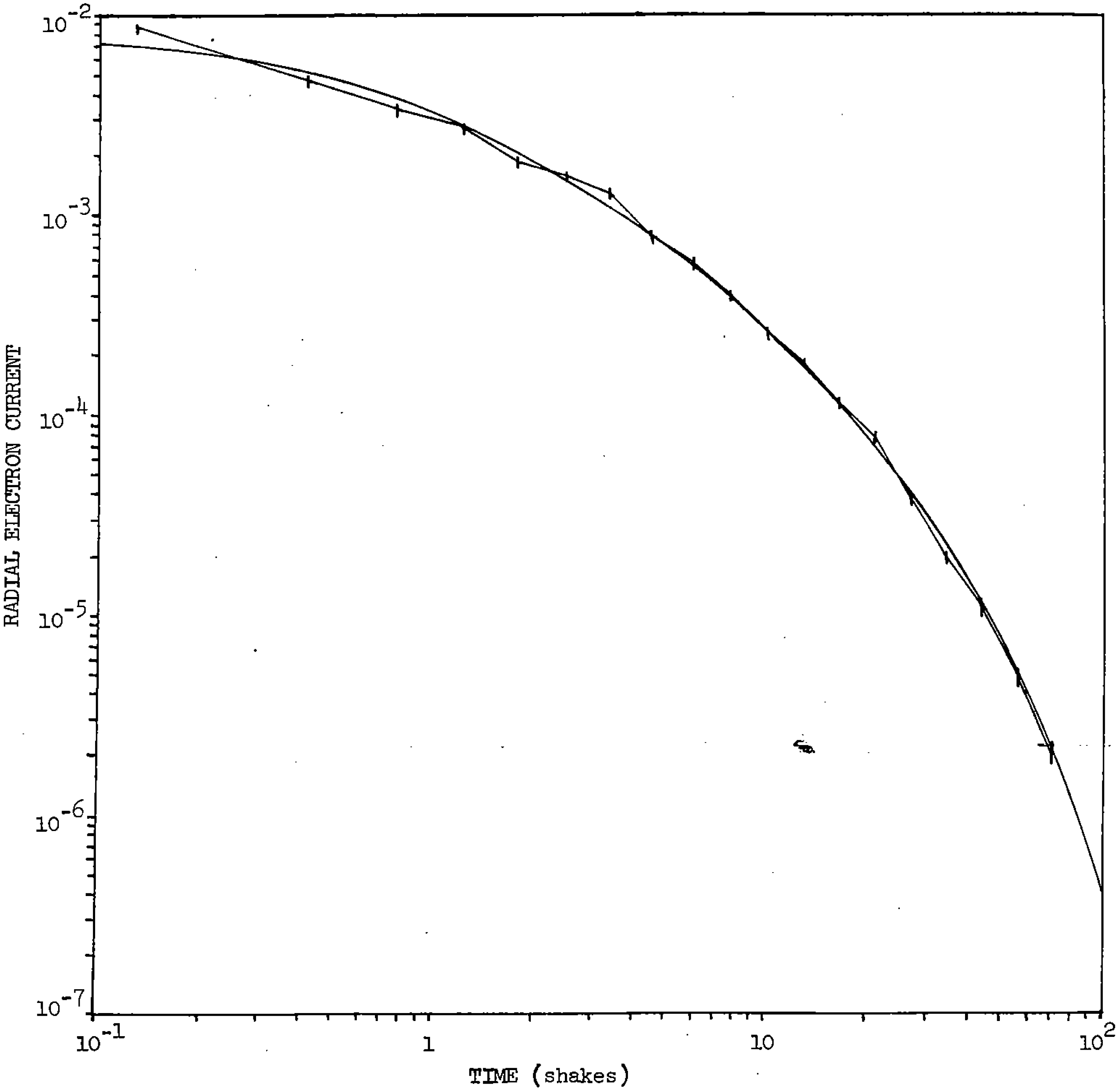


Figure 6.
Radial electron cur[illegible] range [illegible]
of 525 meters; gamma ray energy = 2 mev

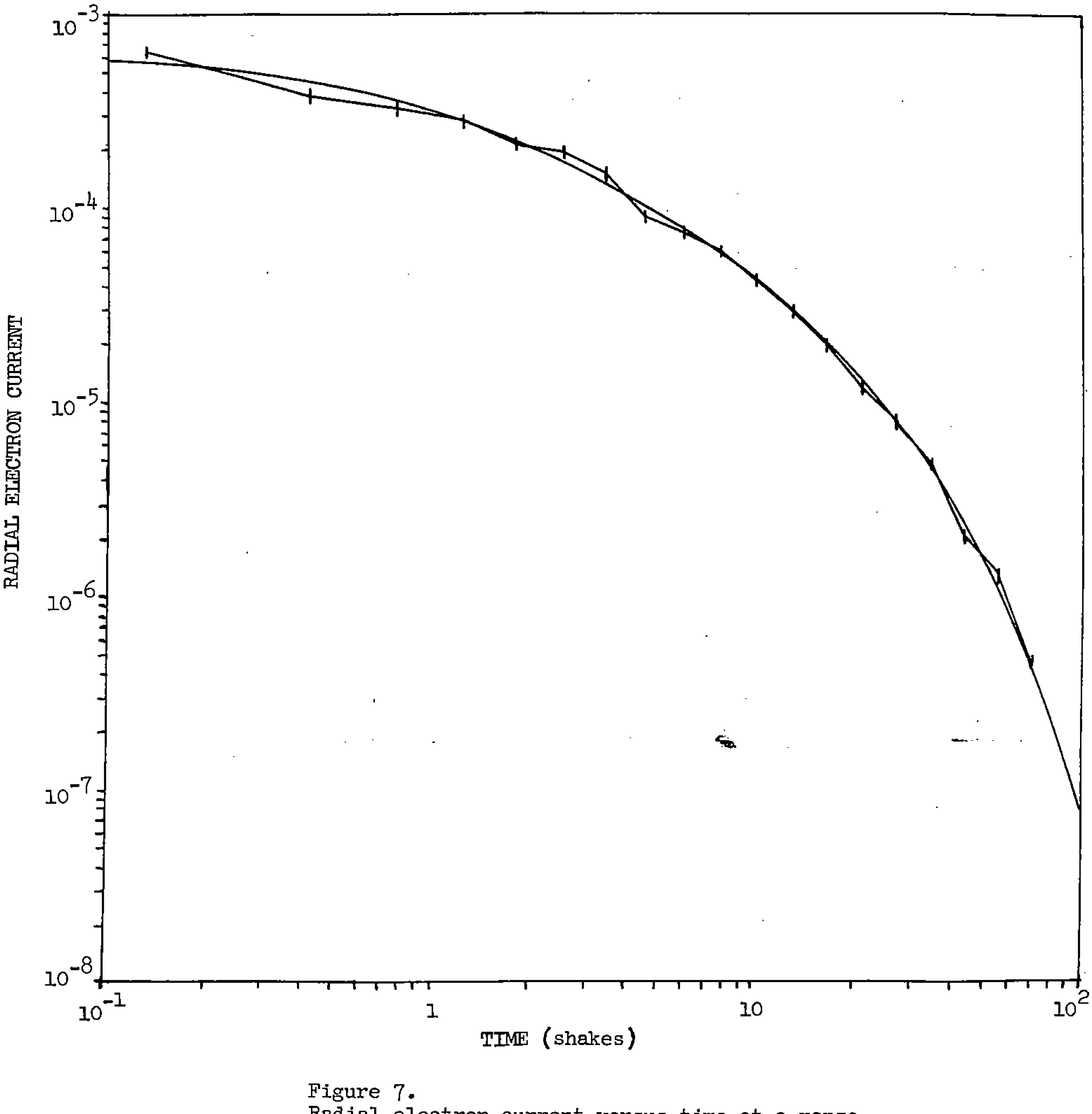
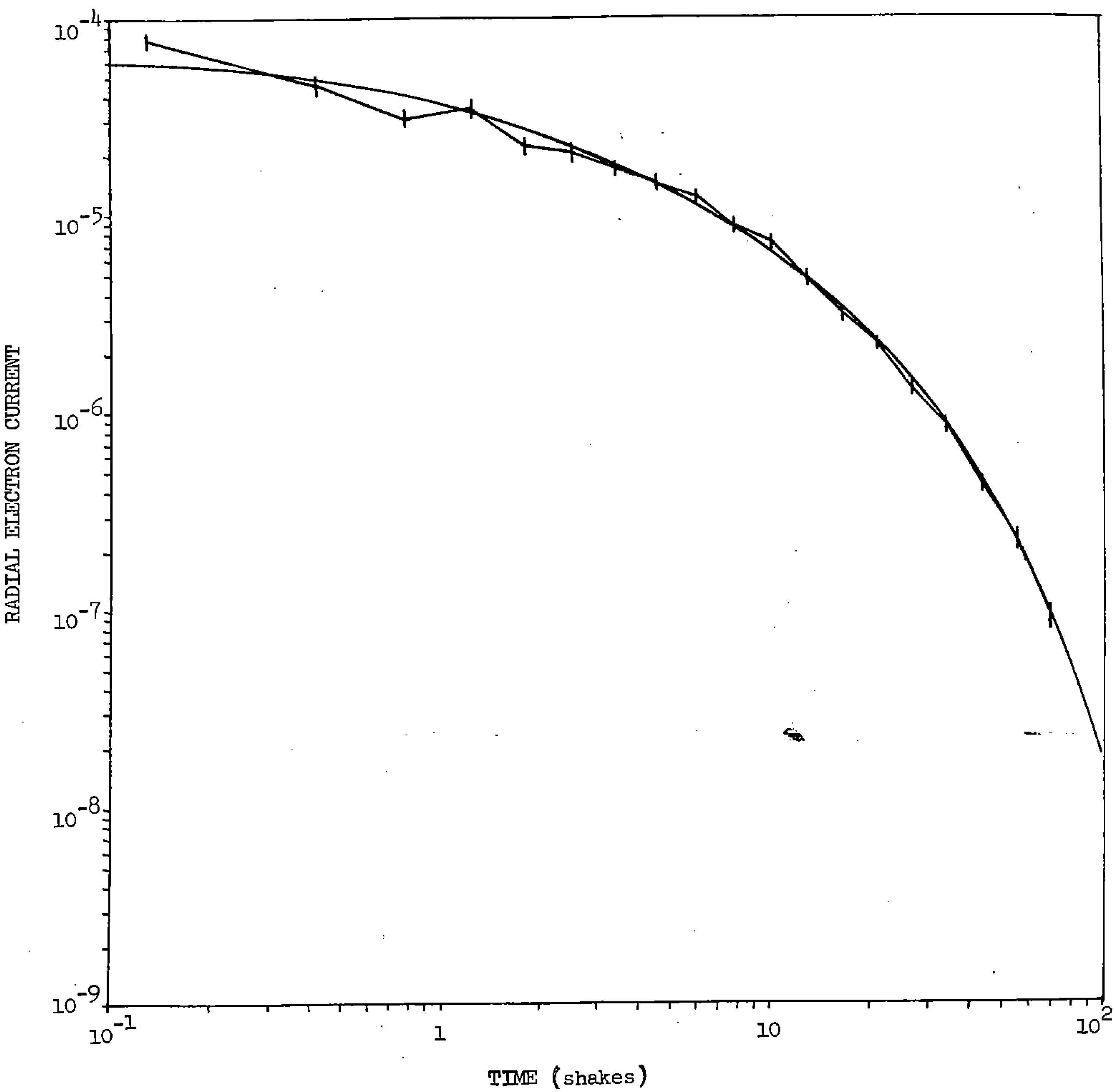


Figure 7.
Radial electron current versus time at a range of 325 meters; gamma ray energy = 2 Mev



Radial electron-current versus time at a range of 1125 meters; gamma ray energy = 2 Mev

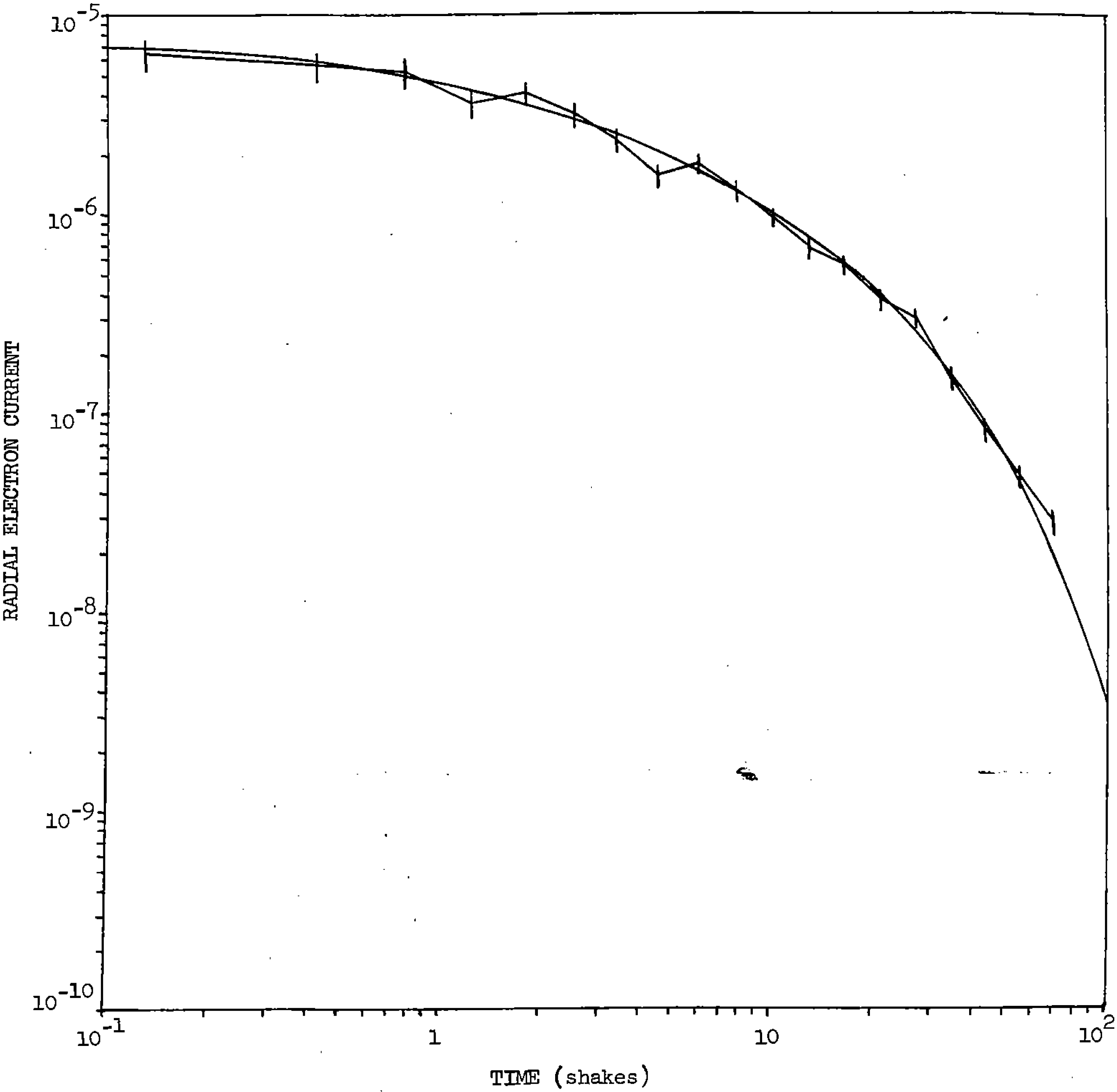


Figure 9.
Radial electron current versus time at a range of 1425 meters; gamma ray energy = 2 Mev

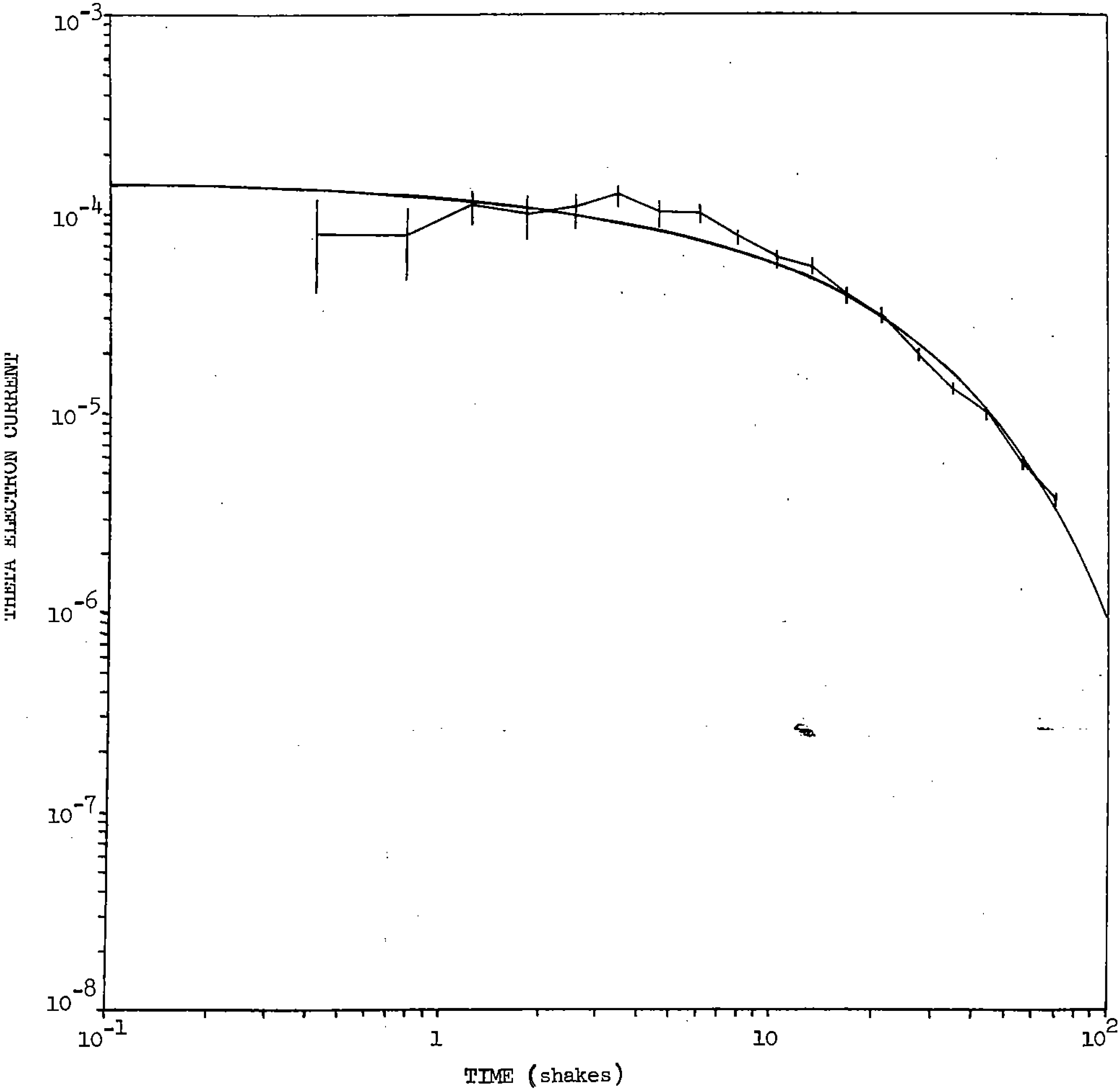


Figure 10.
The [illegible] versus time at a range of 525 meters; gamma ray energy = 2 Mev

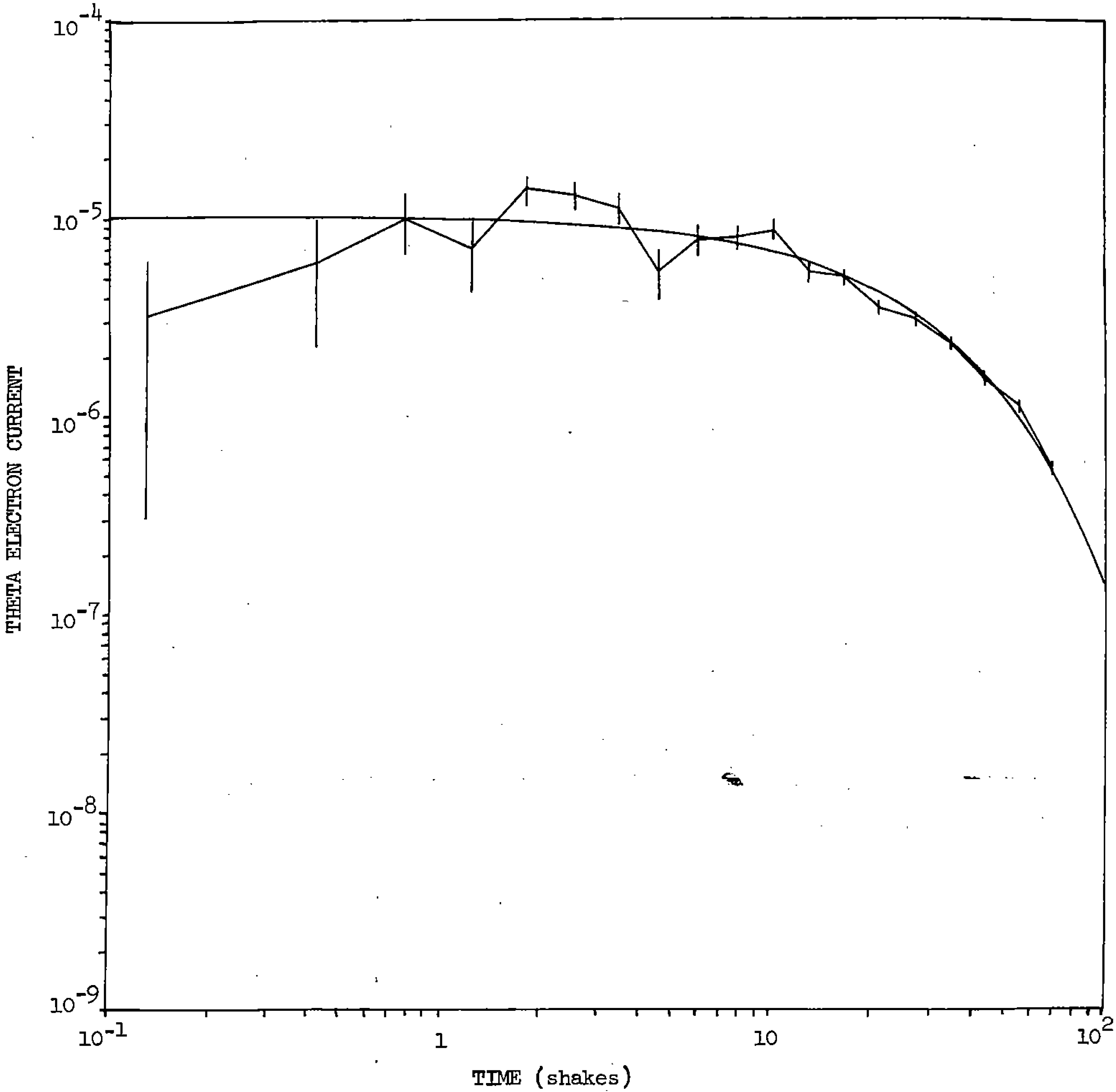


Figure 11.
Theta electron current versus time at a range of 825 meters; gamma ray energy = 2 Mev

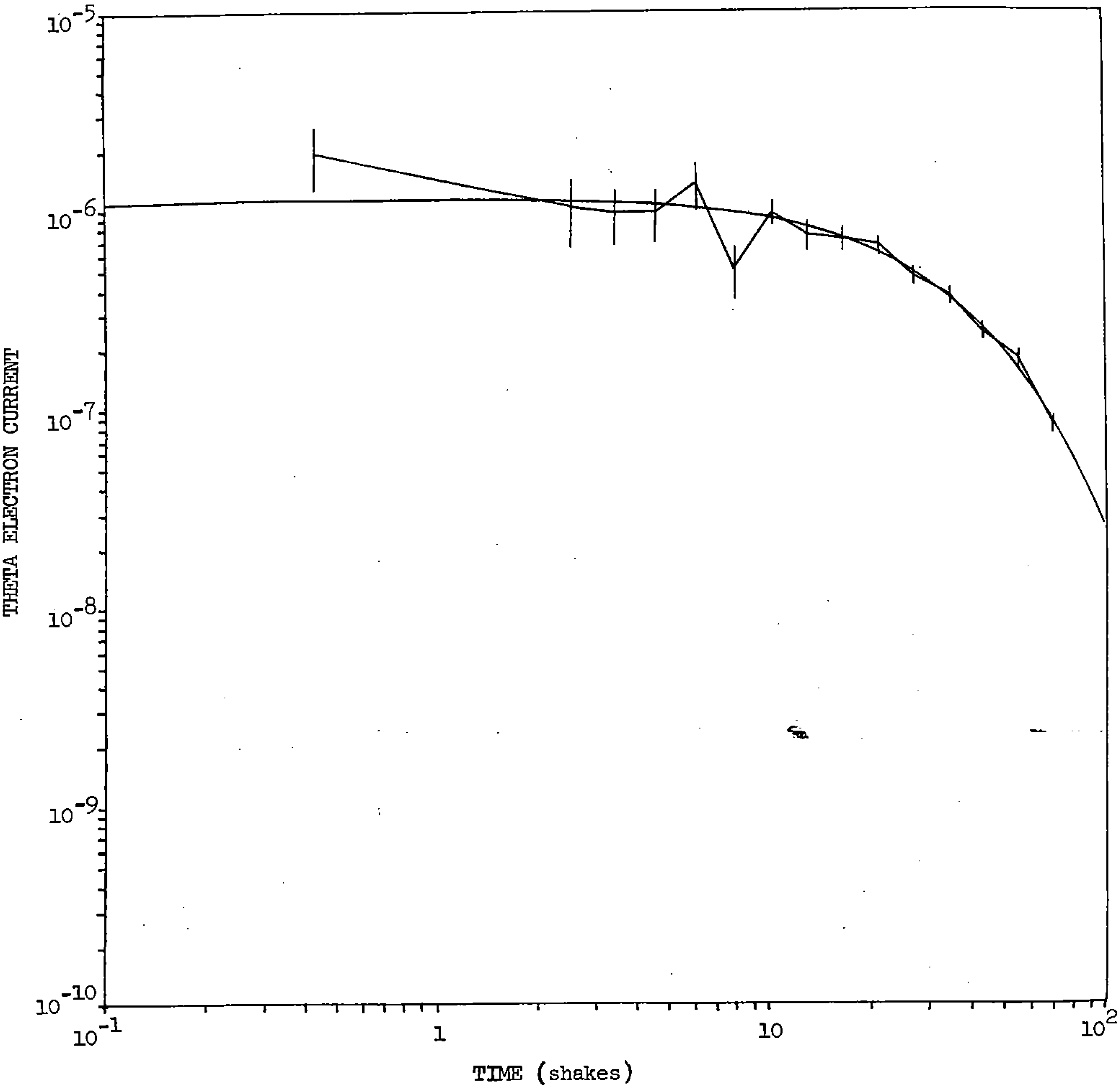


Figure 12.
Theta elect[illegible] at a range of 1125 meters; gamma ray energy = 2 Mev

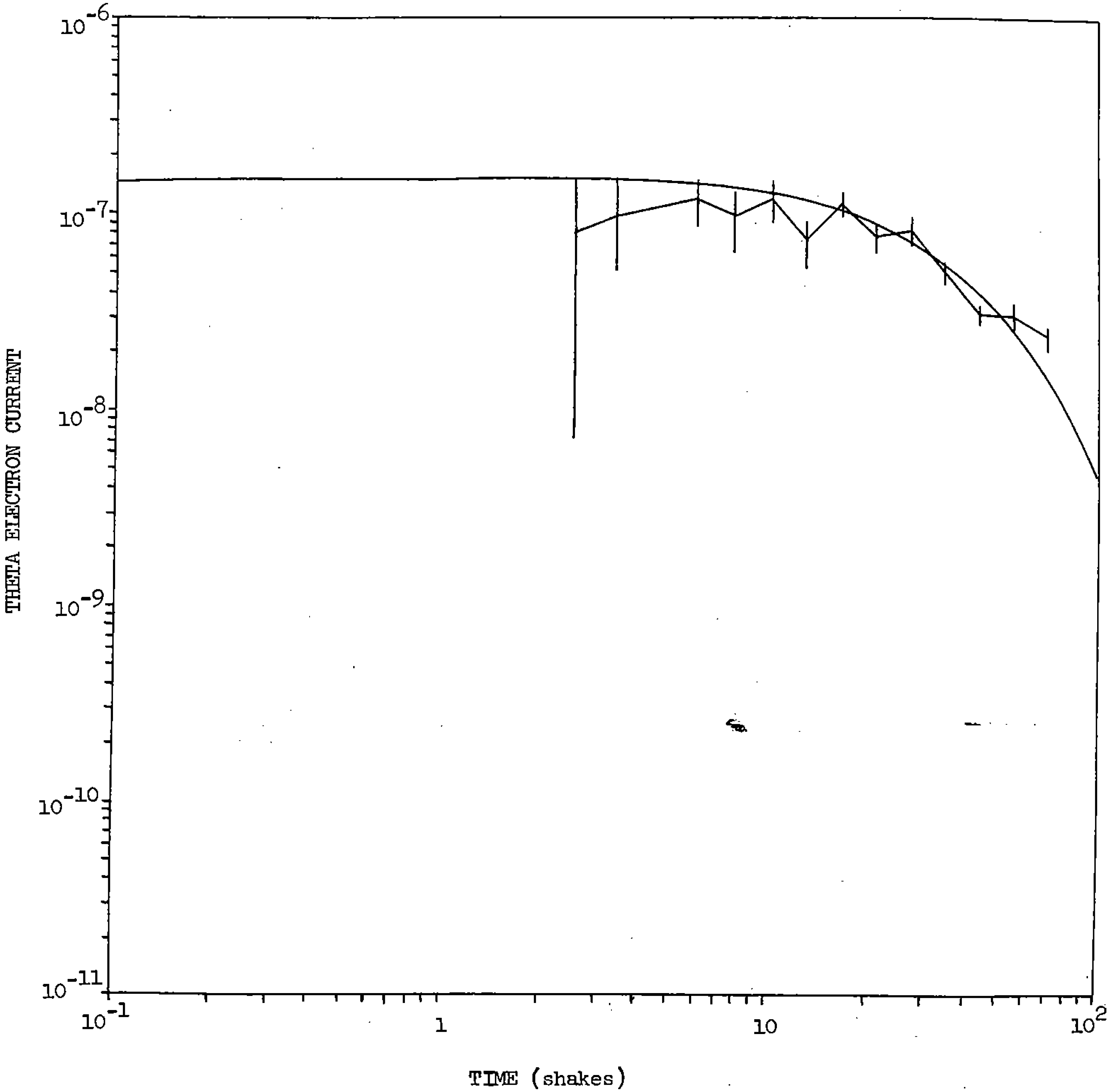


Figure 13.
Theta electron current versus time at a range of 1425 meters; gamma ray energy = 2 Mev

```
 PROGRAM EXAMPLE(INPUT,OUTPUT)
 DIMENSION QTFT(9,8),RTFT(9,8),TTFT(9,8)
 DATA QTFT/
$  1.0742E+03,  7.2868E-01,  1.7959E-02, -8.6245E-03, -8.3214E-03,
$ -8.1446E-03, -1.5256E+00, -7.0602E-01, -3.9550E-01,
$  1.9577E+03,  4.3345E-01,  1.0796E-01, -5.9510E-03, -5.8679E-03,
$ -5.4779E-03, -1.5857E+00, -6.7820E-01, -8.4112E-01,
$  1.4286E+03,  3.6813E-01,  2.0741E-01, -4.9480E-03, -4.7649E-03,
$ -4.4309E-03, -1.4905E+00, -6.8971E-01, -1.0001E+00,
$  8.7250E+02,  5.6869E-01,  3.3132E-01, -4.2186E-03, -3.8732E-03,
$ -3.7416E-03, -1.3955E+00, -8.1386E-01, -1.1171E+00,
$  4.8716E+02,  5.6750E-01,  5.0042E-01, -3.9190E-03, -3.5021E-03,
$ -3.3767E-03, -1.2734E+00, -8.2796E-01, -1.1988E+00,
$  4.2064E+02,  7.2283E-01,  4.5090E-01, -3.5494E-03, -3.1319E-03,
$ -3.0989E-03, -1.2522E+00, -8.9239E-01, -1.1980E+00,
$  3.0209E+02,  1.1351E+00,  1.1202E+00, -3.4292E-03, -2.8103E-03,
$ -2.7919E-03, -1.1795E+00, -9.9063E-01, -1.3658E+00,
$  2.2267E+02,  1.0641E+00,  2.0978E+00, -3.2731E-03, -2.6345E-03,
$ -2.6078E-03, -1.1272E+00, -9.9342E-01, -1.4745E+00/
 DATA RTFT/
$  4.0657E+03,  6.2239E-03,  2.4577E-06, -8.4612E-03, -8.7886E-03,
$ -8.1831E-03, -1.6944E+00,  4.0322E-02,  5.6907E-01,
$  1.0685E+04,  3.6507E-03,  1.8557E-05, -5.8383E-03, -6.3080E-03,
$ -5.3878E-03, -1.7572E+00,  1.1356E-01,  1.0517E-01,
$  1.1056E+04,  3.1278E-03,  1.8719E-04, -4.8207E-03, -5.1634E-03,
$ -4.1171E-03, -1.7026E+00,  1.0940E-01, -3.2477E-01,
$  5.7523E+03,  6.4156E-03,  5.3301E-04, -4.1265E-03, -4.2295E-03,
$ -3.4559E-03, -1.5794E+00, -6.1339E-02, -5.2329E-01,
$  5.3033E+03,  3.9934E-03,  1.8380E-03, -3.8041E-03, -3.9080E-03,
$ -2.9741E-03, -1.5304E+00,  9.1491E-03, -7.5272E-01,
$  5.8170E+03,  3.6103E-03,  4.4007E-03, -3.3951E-03, -3.5769E-03,
$ -2.5379E-03, -1.5512E+00,  3.8108E-04, -9.2352E-01,
$  3.3143E+03,  9.7030E-03,  8.1254E-03, -3.3223E-03, -3.1742E-03,
$ -2.2714E-03, -1.4435E+00, -1.9285E-01, -1.0443E+00,
$  2.8719E+03,  8.0289E-03,  4.9721E-02, -3.1425E-03, -3.0134E-03,
$ -1.9083E-03, -1.4221E+00, -1.7473E-01, -1.3686E+00/
 DATA TTFT/
$  8.5817E+04,  1.9110E-01,  1.1971E-04, -6.6173E-03, -8.3402E-03,
$ -8.2674E-03, -2.9774E+00, -8.0131E-01, -9.9836E-03,
$  9.3091E+04,  1.0746E-01,  5.3946E-04, -4.4925E-03, -5.9777E-03,
$ -5.6072E-03, -2.8625E+00, -7.0595E-01, -3.5186E-01,
$  5.0317E+04,  1.0353E-01,  1.4307E-03, -3.7732E-03, -4.8781E-03,
$ -4.4961E-03, -2.7003E+00, -7.2143E-01, -5.4927E-01,
$  2.8097E+03,  1.4637E-01,  5.1825E-03, -3.6664E-03, -4.1202E-03,
$ -3.7060E-03, -2.1568E+00, -8.0786E-01, -7.8690E-01,
$  1.7742E+03,  1.3876E-01,  4.0989E-03, -3.1332E-03, -3.6720E-03,
$ -3.4251E-03, -2.0506E+00, -8.1407E-01, -7.5988E-01,
$  1.1526E+03,  1.1956E-01,  6.6374E-03, -2.9221E-03, -3.3553E-03,
$ -3.0713E-03, -1.9685E+00, -8.0733E-01, -8.5893E-01,
$  4.2654E+02,  1.8071E-01,  2.2157E-02, -3.1772E-03, -3.1738E-03,
$ -2.7750E-03, -1.7753E+00, -8.8834E-01, -1.0594E+00,
$  5.6626E+02,  1.7574E-01,  5.1830E-02, -2.9261E-03, -3.0050E-03,
$ -2.5812E-03, -1.8626E+00, -8.9786E-01, -1.2097E+00/
```

```
C******************** R = RANGE IN METERS *****************************
      R=3000.
      PRINT 100,R
      PRINT 110
      CALL SAMPLE(R,QTFT)
      PRINT 101,R
      PRINT 110
      CALL SAMPLE(R,RTFT)
      PRINT 102,R
      PRINT 110
      CALL SAMPLE(R,TTFT)
  100 FORMAT(68H1  IONIZATION RATE(MEV/CUBIC METER-SECOND-SOURCE PHOTON)
     $ AT RANGE OF ,F5.0,7H METERS)
  101 FORMAT(71H1  RADIAL CURRENT(ELECTRONS/SQ METER-SECOND-SOURCE PHOTO
     $N) AT RANGE OF ,F5.0,7H METERS)
  102 FORMAT(71H1   THETA CURRENT(ELECTRONS/SQ METER-SECOND-SOURCE PHOTO
     $N) AT RANGE OF ,F5.0,7H METERS)
  110 FORMAT(6X,56HVERSUS TIME(SHAKES) FOR EACH OF THE 8 GAMMA RAY ENERG
     $IES//)
      STOP10
      END
```

```
      SUBROUTINE SAMPLE(R,Q)
      DIMENSION Q(9,8),A(8),B(8),C(8),VAL(8)
      PRINT 103
      DO 10  IE=1,8
   10 CALL ABC(R,Q(1,IE),A(IE),B(IE),C(IE))
      T=-5.
      DO 30  IT=1,21
      T=T+5.
      DO 20  IE=1,8
   20 VAL(IE)=A(IE)*EXP(B(IE)*T)*(T+1.)**C(IE)
   30 PRINT 104,T,VAL
  103 FORMAT(2X,4HTIME,4X,5H1 MEV,5X,5H2 MEV,5X,5H3 MEV.5X,5H4 MEV,5X,
     $5H5 MEV,5X,5H6 MEV,5X,5H7 MEV,5X,5H8 MEV/7H SHAKES/)
  104 FORMAT(F6.1,8E10.2)
      RETURN
      END


      SUBROUTINE ABC(R,Q,A,B,C)
      DIMENSION Q(3,3)
      DATA T1,T2,TL1,TL2/10.,70.,2.397895,4.262680/
      F(X1,X2,X3,X4)=X1*EXP(X2*X4)*X4**X3
      A=F(Q(1,1),Q(1,2),Q(1,3),R)
      F1=F(Q(2,1),Q(2,2),Q(2,3),R)
      F2=F(Q(3,1),Q(3,2),Q(3,3),R)
      DENOM=T1*TL2-T2*TL1
      B=(TL2*ALOG(F1/A)-TL1*ALOG(F2/A))/DENOM
      C=(T1*ALOG(F2/A)-T2*ALOG(F1/A))/DENOM
      RETURN
      END
```

IONIZATION RATE(MEV/CUBIC METER-SECOND-SOURCE PHOTON) AT RANGE OF 1000 METERS
VERSUS TIME(SHAKES) FOR EACH OF THE 8 GAMMA RAY ENERGIES

TIME SHAKES	1 MEV	2 MEV	3 MEV	4 MEV	5 MEV	6 MEV	7 MEV	8 MEV
0.0	5.11E-06	8.92E-05	3.42E-04	8.36E-04	1.46E-03	2.12E-03	2.83E-03	3.50E-03
5.0	1.92E-06	1.96E-05	5.20E-05	9.15E-05	1.28E-04	1.58E-04	1.82E-04	2.05E-04
10.0	1.35E-06	1.13E-05	2.68E-05	4.28E-05	5.61E-05	6.63E-05	7.29E-05	7.99E-05
15.0	1.07E-06	7.93E-06	1.75E-05	2.65E-05	3.37E-05	3.90E-05	4.18E-05	4.52E-05
20.0	8.99E-07	6.03E-06	1.27E-05	1.87E-05	2.32E-05	2.66E-05	2.82E-05	3.02E-05
25.0	7.77E-07	4.82E-06	9.82E-06	1.41E-05	1.73E-05	1.98E-05	2.08E-05	2.21E-05
30.0	6.85E-07	3.97E-06	7.89E-06	1.12E-05	1.36E-05	1.55E-05	1.62E-05	1.72E-05
35.0	6.12E-07	3.34E-06	6.50E-06	9.14E-06	1.11E-05	1.26E-05	1.32E-05	1.39E-05
40.0	5.53E-07	2.86E-06	5.47E-06	7.65E-06	9.26E-06	1.06E-05	1.11E-05	1.17E-05
45.0	5.04E-07	2.47E-06	4.68E-06	6.53E-06	7.90E-06	9.10E-06	9.48E-06	1.00E-05
50.0	4.61E-07	2.16E-06	4.05E-06	5.65E-06	6.85E-06	7.94E-06	8.29E-06	8.76E-06
55.0	4.25E-07	1.91E-06	3.54E-06	4.94E-06	6.02E-06	7.02E-06	7.35E-06	7.77E-06
60.0	3.93E-07	1.69E-06	3.12E-06	4.37E-06	5.35E-06	6.28E-06	6.60E-06	6.99E-06
65.0	3.65E-07	1.51E-06	2.76E-06	3.90E-06	4.79E-06	5.68E-06	5.99E-06	6.36E-06
70.0	3.39E-07	1.35E-06	2.47E-06	3.50E-06	4.33E-06	5.18E-06	5.49E-06	5.83E-06
75.0	3.17E-07	1.22E-06	2.21E-06	3.16E-06	3.94E-06	4.76E-06	5.06E-06	5.39E-06
80.0	2.96E-07	1.10E-06	1.99E-06	2.87E-06	3.60E-06	4.39E-06	4.70E-06	5.02E-06
85.0	2.78E-07	9.95E-07	1.80E-06	2.62E-06	3.31E-06	4.08E-06	4.40E-06	4.70E-06
90.0	2.61E-07	9.04E-07	1.64E-06	2.40E-06	3.06E-06	3.81E-06	4.13E-06	4.43E-06
95.0	2.45E-07	8.23E-07	1.49E-06	2.21E-06	2.84E-06	3.58E-06	3.90E-06	4.20E-06
100.0	2.31E-07	7.51E-07	1.36E-06	2.04E-06	2.64E-06	3.37E-06	3.69E-06	3.99E-06

RADIAL CURRENT(ELECTRONS/SQ METER-SECOND-SOURCE PHOTON) AT RANGE OF 1000 METERS
VERSUS TIME(SHAKES) FOR EACH OF THE 8 GAMMA RAY ENERGIES

TIME SHAKES	1 MEV	2 MEV	3 MEV	4 MEV	5 MEV	6 MEV	7 MEV	8 MEV
0.0	7.10E-06	1.67E-04	6.95E-04	1.70E-03	3.03E-03	4.33E-03	5.59E-03	6.72E-03
5.0	2.16E-06	3.04E-05	8.94E-05	1.58E-04	2.35E-04	2.91E-04	3.21E-04	3.63E-04
10.0	1.25E-06	1.46E-05	3.81E-05	6.11E-05	8.54E-05	1.01E-04	1.07E-04	1.18E-04
15.0	8.26E-07	8.43E-06	2.05E-05	3.12E-05	4.20E-05	4.86E-05	5.03E-05	5.44E-05
20.0	5.75E-07	5.31E-06	1.23E-05	1.80E-05	2.36E-05	2.69E-05	2.76E-05	2.93E-05
25.0	4.13E-07	3.50E-06	7.77E-06	1.12E-05	1.43E-05	1.62E-05	1.65E-05	1.72E-05
30.0	3.03E-07	2.38E-06	5.11E-06	7.25E-06	9.08E-06	1.02E-05	1.04E-05	1.07E-05
35.0	2.26E-07	1.66E-06	3.46E-06	4.85E-06	5.98E-06	6.73E-06	6.82E-06	6.94E-06
40.0	1.70E-07	1.17E-06	2.38E-06	3.32E-06	4.04E-06	4.54E-06	4.61E-06	4.63E-06
45.0	1.29E-07	8.37E-07	1.67E-06	2.32E-06	2.78E-06	3.13E-06	3.18E-06	3.16E-06
50.0	9.84E-08	6.04E-07	1.18E-06	1.64E-06	1.95E-06	2.19E-06	2.24E-06	2.19E-06
55.0	7.56E-08	4.40E-07	8.46E-07	1.17E-06	1.38E-06	1.55E-06	1.60E-06	1.55E-06
60.0	5.82E-08	3.22E-07	6.10E-07	8.48E-07	9.87E-07	1.12E-06	1.15E-06	1.10E-06
65.0	4.51E-08	2.37E-07	4.43E-07	6.17E-07	7.12E-07	8.08E-07	8.40E-07	7.95E-07
70.0	3.50E-08	1.75E-07	3.24E-07	4.53E-07	5.18E-07	5.90E-07	6.17E-07	5.78E-07
75.0	2.72E-08	1.30E-07	2.38E-07	3.34E-07	3.79E-07	4.34E-07	4.57E-07	4.23E-07
80.0	2.12E-08	9.72E-08	1.75E-07	2.48E-07	2.79E-07	3.21E-07	3.41E-07	3.12E-07
85.0	1.66E-08	7.27E-08	1.30E-07	1.85E-07	2.07E-07	2.39E-07	2.56E-07	2.32E-07
90.0	1.30E-08	5.45E-08	9.63E-08	1.38E-07	1.54E-07	1.78E-07	1.93E-07	1.73E-07
95.0	1.02E-08	4.10E-08	7.17E-08	1.04E-07	1.15E-07	1.34E-07	1.46E-07	1.29E-07
100.0	8.02E-09	3.09E-08	5.36E-08	7.82E-08	8.59E-08	1.01E-07	1.11E-07	9.72E-08

THETA CURRENT(ELECTRONS/SQ METER-SECOND-SOURCE PHOTON) AT RANGE OF 1000 METERS VERSUS TIME(SHAKES) FOR EACH OF THE 8 GAMMA RAY ENERGIES

TIME SHAKES	1 MEV	2 MEV	3 MEV	4 MEV	5 MEV	6 MEV	7 MEV	8 MEV
0.0	1.34E-07	2.69E-06	9.17E-06	2.43E-05	5.45E-05	7.71E-05	8.40E-05	7.84E-05
5.0	1.84E-07	2.47E-06	6.88E-06	1.27E-05	2.00E-05	2.56E-05	2.67E-05	2.80E-05
10.0	1.80E-07	2.08E-06	5.40E-06	8.96E-06	1.27E-05	1.58E-05	1.64E-05	1.76E-05
15.0	1.64E-07	1.72E-06	4.27E-06	6.72E-06	9.04E-06	1.10E-05	1.14E-05	1.24E-05
20.0	1.46E-07	1.41E-06	3.39E-06	5.17E-06	6.72E-06	8.08E-06	8.40E-06	9.18E-06
25.0	1.27E-07	1.15E-06	2.70E-06	4.04E-06	5.14E-06	6.13E-06	6.40E-06	6.98E-06
30.0	1.10E-07	9.37E-07	2.15E-06	3.19E-06	4.00E-06	4.73E-06	4.97E-06	5.40E-06
35.0	9.42E-08	7.62E-07	1.72E-06	2.53E-06	3.15E-06	3.71E-06	3.93E-06	4.24E-06
40.0	8.02E-08	6.19E-07	1.37E-06	2.02E-06	2.50E-06	2.94E-06	3.13E-06	3.35E-06
45.0	6.80E-08	5.02E-07	1.10E-06	1.62E-06	2.00E-06	2.34E-06	2.52E-06	2.67E-06
50.0	5.75E-08	4.07E-07	8.77E-07	1.30E-06	1.61E-06	1.88E-06	2.04E-06	2.14E-06
55.0	4.85E-08	3.29E-07	7.01E-07	1.05E-06	1.30E-06	1.52E-06	1.66E-06	1.73E-06
60.0	4.08E-08	2.66E-07	5.61E-07	8.47E-07	1.06E-06	1.23E-06	1.36E-06	1.40E-06
65.0	3.42E-08	2.16E-07	4.49E-07	6.85E-07	8.59E-07	1.00E-06	1.11E-06	1.13E-06
70.0	2.87E-08	1.74E-07	3.59E-07	5.55E-07	7.01E-07	8.15E-07	9.17E-07	9.21E-07
75.0	2.40E-08	1.41E-07	2.87E-07	4.50E-07	5.73E-07	6.67E-07	7.57E-07	7.51E-07
80.0	2.01E-08	1.14E-07	2.30E-07	3.66E-07	4.70E-07	5.46E-07	6.26E-07	6.14E-07
85.0	1.68E-08	9.19E-08	1.84E-07	2.97E-07	3.85E-07	4.49E-07	5.19E-07	5.03E-07
90.0	1.40E-08	7.42E-08	1.47E-07	2.42E-07	3.17E-07	3.69E-07	4.31E-07	4.12E-07
95.0	1.16E-08	5.99E-08	1.18E-07	1.97E-07	2.61E-07	3.04E-07	3.59E-07	3.38E-07
100.0	9.69E-09	4.84E-08	9.46E-08	1.60E-07	2.15E-07	2.51E-07	2.99E-07	2.78E-07

ONIZATION RATE(MEV/CUBIC METER-SECOND-SOURCE PHOTON) AT RANGE OF 3000 METERS
VERSUS TIME(SHAKES) FOR EACH OF THE 8 GAMMA RAY ENERGIES

TIME SHAKES	1 MEV	2 MEV	3 MEV	4 MEV	5 MEV	6 MEV	7 MEV	8 MEV
0.0	3.09E-14	1.06E-10	3.35E-09	3.91E-08	1.43E-07	4.42E-07	8.15E-07	1.46E-06
5.0	3.66E-14	5.62E-11	1.33E-09	1.22E-08	3.55E-08	8.77E-08	1.65E-07	2.66E-07
10.0	3.68E-14	4.30E-11	9.11E-10	7.56E-09	2.05E-08	4.74E-08	8.89E-08	1.38E-07
15.0	3.58E-14	3.54E-11	6.94E-10	5.37E-09	1.40E-08	3.11E-08	5.80E-08	8.80E-08
20.0	3.44E-14	3.01E-11	5.54E-10	4.05E-09	1.03E-08	2.23E-08	4.11E-08	6.13E-08
[illegible]	3.27E-14	2.60E-11	4.55E-10	3.16E-09	7.86E-09	1.68E-08	3.06E-08	4.50E-08
[illegible]	3.10E-14	2.28E-11	3.79E-10	2.52E-09	6.17E-09	1.30E-08	2.35E-08	3.42E-08
[illegible]	2.93E-14	2.01E-11	3.21E-10	2.04E-09	4.94E-09	1.04E-08	1.85E-08	2.66E-08
[illegible]	2.75E-14	1.78E-11	2.73E-10	1.67E-09	4.01E-09	8.37E-09	1.47E-08	2.10E-08
[illegible]	2.59E-14	1.59E-11	2.34E-10	1.38E-09	3.29E-09	6.85E-09	1.19E-08	1.68E-08
[illegible]	2.42E-14	1.42E-11	2.02E-10	1.15E-09	2.72E-09	5.66E-09	9.71E-09	1.36E-08
[illegible]	2.27E-14	1.28E-11	1.75E-10	9.61E-10	2.27E-09	4.71E-09	7.99E-09	1.11E-08
[illegible]	2.12E-14	1.15E-11	1.53E-10	8.08E-10	1.90E-09	3.95E-09	6.61E-09	9.12E-09
[illegible]	1.98E-14	1.04E-11	1.33E-10	6.81E-10	1.60E-09	3.33E-09	5.50E-09	7.54E-09
[illegible]	1.85E-14	9.37E-12	1.17E-10	5.77E-10	1.35E-09	2.82E-09	4.60E-09	6.27E-09
[illegible]	1.73E-14	8.47E-12	1.02E-10	4.90E-10	1.15E-09	2.40E-09	3.86E-09	5.23E-09
[illegible]	1.61E-14	7.68E-12	8.98E-11	4.17E-10	9.77E-10	2.05E-09	3.25E-09	4.38E-09
[illegible]	1.50E-14	6.97E-12	7.91E-11	3.56E-10	8.34E-10	1.76E-09	2.75E-09	3.69E-09
90.0	1.40E-14	6.33E-12	6.97E-11	3.04E-10	7.13E-10	1.51E-09	2.33E-09	3.11E-09
95.0	1.30E-14	5.75E-12	6.15E-11	2.60E-10	6.12E-10	1.30E-09	1.98E-09	2.63E-09
100.0	1.21E-14	5.23E-12	5.44E-11	2.23E-10	5.25E-10	1.13E-09	1.69E-09	2.23E-09

RADIAL CURRENT(ELECTRONS/SQ METER-SECOND-SOURCE PHOTON) AT RANGE OF 3000 METERS
VERSUS TIME(SHAKES) FOR EACH OF THE 8 GAMMA RAY ENERGIES

TIME SHAKES	1 MEV	2 MEV	3 MEV	4 MEV	5 MEV	6 MEV	7 MEV	8 MEV
0.0	4.94E-14	2.05E-10	6.96E-09	7.79E-08	2.80E-07	8.86E-07	1.49E-06	2.62E-06
5.0	3.68E-14	8.24E-11	2.31E-09	2.17E-08	6.62E-08	1.62E-07	3.04E-07	4.88E-07
10.0	3.05E-14	5.48E-11	1.41E-09	1.21E-08	3.48E-08	7.92E-08	1.52E-07	2.35E-07
15.0	2.57E-14	4.02E-11	9.67E-10	7.73E-09	2.14E-08	4.70E-08	8.99E-08	1.36E-07
20.0	2.20E-14	3.08E-11	7.00E-10	5.23E-09	1.41E-08	3.03E-08	5.77E-08	8.59E-08
25.0	1.88E-14	2.43E-11	5.22E-10	3.66E-09	9.64E-09	2.06E-08	3.86E-08	5.67E-08
30.0	1.62E-14	1.94E-11	3.97E-10	2.62E-09	6.77E-09	1.44E-08	2.66E-08	3.86E-08
35.0	1.40E-14	1.57E-11	3.07E-10	1.91E-09	4.84E-09	1.03E-08	1.87E-08	2.68E-08
40.0	1.20E-14	1.28E-11	2.39E-10	1.40E-09	3.51E-09	7.48E-09	1.33E-08	1.89E-08
45.0	1.04E-14	1.05E-11	1.87E-10	1.04E-09	2.56E-09	5.50E-09	9.61E-09	1.35E-08
50.0	9.02E-15	8.62E-12	1.48E-10	7.77E-10	1.89E-09	4.09E-09	7.00E-09	9.77E-09
55.0	7.81E-15	7.13E-12	1.18E-10	5.84E-10	1.40E-09	3.06E-09	5.13E-09	7.10E-09
60.0	6.77E-15	5.92E-12	9.37E-11	4.41E-10	1.05E-09	2.31E-09	3.78E-09	5.20E-09
65.0	5.88E-15	4.93E-12	7.49E-11	3.34E-10	7.86E-10	1.75E-09	2.80E-09	3.83E-09
70.0	5.10E-15	4.12E-12	6.01E-11	2.54E-10	5.92E-10	1.34E-09	2.09E-09	2.83E-09
75.0	4.43E-15	3.44E-12	4.83E-11	1.94E-10	4.47E-10	1.02E-09	1.56E-09	2.10E-09
80.0	3.85E-15	2.89E-12	3.00E-11	1.48E-10	3.39E-10	7.85E-10	1.17E-09	1.56E-09
85.0	3.34E-15	2.42E-12	3.15E-11	1.13E-10	2.57E-10	6.05E-10	8.78E-10	1.17E-09
90.0	2.91E-15	2.04E-12	2.55E-11	8.70E-11	1.96E-10	4.67E-10	6.62E-10	8.75E-10
95.0	2.53E-15	1.71E-12	2.06E-11	6.69E-11	1.49E-10	3.62E-10	5.00E-10	6.57E-10
100.0	2.20E-15	1.44E-12	1.67E-11	5.15E-11	1.14E-10	2.81E-10	3.78E-10	4.94E-10

THETA CURRENT(ELECTRONS/SQ METER-SECOND-SOURCE PHOTON) AT RANGE OF 3000 METERS
VERSUS TIME(SHAKES) FOR EACH OF THE 8 GAMMA RAY ENERGIES

ME S[illegible]KES	1 MEV	2 MEV	3 MEV	4 MEV	5 MEV	6 MEV	7 MEV	8 MEV
[illegible].0	9.10E-15	1.45E-11	2.49E-10	1.49E-09	1.09E-08	2.57E-08	2.08E-08	2.91E-08
[illegible].0	5.21E-15	7.89E-12	1.74E-10	1.17E-09	4.85E-09	1.15E-08	1.38E-08	2.06E-08
1[illegible].0	4.25E-15	6.14E-12	1.42E-10	9.73E-10	3.37E-09	7.92E-09	1.08E-08	1.61E-08
1[illegible].0	3.72E-15	5.13E-12	1.19E-10	8.20E-10	2.55E-09	5.96E-09	8.67E-09	1.29E-08
2[illegible].0	3.35E-15	4.43E-12	1.01E-10	6.94E-10	2.01E-09	4.65E-09	7.07E-09	1.04E-08
25.0	3.08E-15	3.89E-12	8.67E-11	5.89E-10	1.62E-09	3.71E-09	5.80E-09	8.46E-09
30.0	2.86E-15	3.45E-12	7.47E-11	5.01E-10	1.32E-09	3.00E-09	4.79E-09	6.88E-09
35.0	2.67E-15	3.09E-12	6.45E-11	4.27E-10	1.09E-09	2.45E-09	3.97E-09	5.62E-09
40.0	2.52E-15	2.79E-12	5.59E-11	3.64E-10	9.02E-10	2.02E-09	3.29E-09	4.59E-09
45.0	2.38E-15	2.52E-12	4.86E-11	3.10E-10	7.53E-10	1.67E-09	2.74E-09	3.76E-09
50.0	2.25E-15	2.29E-12	4.22E-11	2.65E-10	6.32E-10	1.39E-09	2.28E-09	3.08E-09
5[illegible].0	2.14E-15	2.08E-12	3.68E-11	2.26E-10	5.32E-10	1.16E-09	1.90E-09	2.52E-09
[illegible].0	2.05E-15	1.90E-12	3.21E-11	1.93E-10	4.49E-10	9.68E-10	1.59E-09	2.07E-09
[illegible].0	1.95E-15	1.74E-12	2.80E-11	1.65E-10	3.80E-10	8.12E-10	1.33E-09	1.70E-09
[illegible].0	1.87E-15	1.60E-12	2.44E-11	1.41E-10	3.22E-10	6.82E-10	1.11E-09	1.40E-09
[illegible].0	1.79E-15	1.46E-12	2.13E-11	1.21E-10	2.74E-10	5.74E-10	9.31E-10	1.15E-09
[illegible].0	1.72E-15	1.35E-12	1.87E-11	1.03E-10	2.33E-10	4.84E-10	7.80E-10	9.44E-10
[illegible].0	1.65E-15	1.24E-12	1.63E-11	8.83E-11	1.98E-10	4.09E-10	6.54E-10	7.76E-10
[illegible].0	1.59E-15	1.14E-12	1.43E-11	7.56E-11	1.69E-10	3.46E-10	5.48E-10	6.39E-10
[illegible].0	1.53E-15	1.05E-12	1.25E-11	6.47E-11	1.45E-10	2.92E-10	4.60E-10	5.26E-10
1[illegible].0	1.48E-15	9.71E-13	1.09E-11	5.53E-11	1.24E-10	2.48E-10	3.86E-10	4.33E-10