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Publication Date
1968-07-01

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Berkeley, California

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UCRL-17663 Rev. 1
UC-34 Physics
TID-4500 (52nd Ed.)

UNIVERSITY OF CALIFORNIA
Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

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A RANGE ENERGY TABLE FOR HEAVY PARTICLES IN SILICON*

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Abstract

Stopping-power S and range R tables for protons, deuterons, tritons, He^3, He^4 and Li^7 ions of energies between 1- and 200-MeV penetrating silicon absorbers are presented. Auxiliary data include tables for the coefficients C and α needed for the approximate expression $S = C \cdot E^{\alpha}$ and figures giving the energy dependence for the coefficients of $R = C_R \cdot E^{\beta}$. A short review is given of principles to be considered in detector applications.

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*Work supported in part by the U.S. Atomic Energy Commission and Public Health Service Research Grant No. CA 08150 from the National Cancer Institute.

†On leave of absence from the University of Southern California, Los Angeles.

‡Now at Rutherford High Energy Laboratory, Didcot, England.

1. Introduction

Since silicon detectors have found wide spread applications, energy-loss tables for heavy particles are a necessity. Recent accurate measurements for protons[11,33]) permit the presentation of calculated tables with a better basis than previous calculations. In particular it was found that the difference of the I-values of Al and Si is only about 7 eV rather than 12.5 eV as would be expected from a statistical model[2]). There still are unresolved differences between experimental data[21]) and some changes may have to be made in these tables as further results become available. A number of auxiliary tables and figures useful for the design and evaluation of particle-identifier systems are presented.

2. General Basis for Stopping-Power and Range-Energy Tables

2.1. Theory

The mean energy loss S of energetic charged particles in matter has been derived by Bethe[1], and is extensively discussed by Fano[2]. For the present application to silicon, the following expression will be used[3,4]:

$$S = (0.30706\, z^2/A\cdot\beta^2)\{Z[f(\beta) - \ln I] - C_K - C_L\} \qquad (1)$$

where

ze = charge of incident particle

A = 28.086 = chemical atomic weight of silicon

β = v/c = velocity of particle/velocity of light

Z = 14 = atomic number of silicon

$f(\beta) = \ln[2\, mc^2\beta^2/(1 - \beta^2)] - \beta^2$

I = 173.5 eV = mean ionization potential of Si (ref. 11)

C_K = Walske's K-shell correction[5]

C_L = Walske's L-shell correction[6], modified to fit experimental data[7,8]

$\beta^2 = \zeta(\zeta+2)/(\zeta+1)^2$ where $\zeta = E/Mc^2$

E = kinetic energy of particle of restmass M.

For a discussion of the effective charge at low velocities, see ref. 3 or 4.

The ranges R in the continuous slowing down approximation[2] (csda) are calculated from S:

$$R = \int_{1\,\text{MeV}}^{E} (1/S)\,dE + R(1\ \text{MeV}). \qquad (2)$$

2.2. Applications to experiments

A number of relatively small corrections should be considered for the use in experiments of S and R as defined above.

The distribution functions in energy E observed after a beam of particles has traversed a foil ("straggling distributions") are asymmetric, especially for small energy losses[9,10], but even for a final energy of $E_1 \sim 0.2$ E, a straggling asymmetry is still found[11,34]. In addition, an asymmetry is caused by multiple scattering[7,11]. It gets larger with thicker absorbers. A detailed discussion is given in Ref. 12. The multiple scattering correction for total ranges can be obtained from fig. 1.

At particle energies in excess of a few MeV, nuclear reactions will cause a perceptible attenuation of the beam intensity[3,13,14]. A rough estimate can be obtained with the following equation

$$I/I_o = e^{-\Delta/L} \qquad (3)$$

where I/I_o is the fraction of the beam transmitted through an absorber of thickness Δ and the mean free path length is given for protons by

$$L \sim 31 \cdot A^{1/3} \text{ g cm}^{-2} . \qquad (4)$$

For particle identification applications, these effects are usually small and can be partially avoided by the use of more sophisticated instrumentation (systems with three or more counters, anticoincidence arrangements etc).

The Lewis correction[15]), the difference between the actual path-length and the csda range, is usually less than 0.1% for protons and heavier particles.

2.3. Stopping-power and range tables

While accurate energy-loss measurements[11]) in silicon are available for protons with energies between 3 and 30 MeV, the determination of the parameters at low energies leans heavily on the data for aluminum[7,8]). It has been assumed that eq. (1) applies equally well to Al and Si, in particular that the L-shell correction can be scaled using Walske's η_L.

For the starting ranges R (1 MeV), measured values are available for protons[7]), tritons[16]) and α particles[17,18]) in aluminum. The following procedure was sed to get starting ranges for the other particles: ranges were calculated for particles from 0.25 to 1 MeV. The ratio of measured to calculated range was then used for the other particles. Errors of at least ±0.2 mg cm^{-2} should be assigned to the starting ranges. The starting ranges for Si were assumed to be 0.981 of the Al values. The accurate energy-loss measurements for heavy ions in Al of ref. (19) are not suitable to give starting values for the ranges. Further measurements would be highly desirable.

The charge-state corrections are not well-known for Li^7 ions, and therefore the tables will be accurate only to a few percent below about 5 MeV.

The stopping power S for p, d, t, He^3, He^4 and Li^7 ions in silicon is given in Table 1. The csda ranges R for the same ions are given in Table 2. For both tables, linear interpolation will give an accuracy of 0.1%. Since the tables are a direct printout of computer output, it was not practical to change the number of digits presented, and this number is not to be considered indicative of the accuracy of the tables. An I-value of 173.5 eV was used for the calculation[11].

2.4. Comparison with experimental data

The silicon range curve for protons deviates by less than 0.2% from the experimental data of ref. (11) for the energy range from 3 to 30 MeV. An older measurement[20] gives an absorber thickness of 0.985 mg cm^{-2} of Si to be equivalent to 1.00 mg cm^{-2} of Al for 8-MeV deuterons. Nothing is said about the composition of the samples or the assumed density. From Table 2, the corresponding number is about 0.979, depending on what lower energy is used. See Ref. 33 for stopping power measurements.

To get a fair estimate of the overall accuracy, the following data should be considered, based on a calculation of Al ranges and stopping power with I = 166 eV (from ref. (11)).

It was found[21] that there exists a difference of up to 1% between the proton energy-loss measurements of ref. (11) and the stopping-power measurements of ref. (8). No explanation for this difference has been forwarded so far.

For the α-particle ranges there is a systematic deviation of between 3 and 7% from the experimental data of ref. (17), and about 3% from ref. (18). Since I = 166 eV was used for Al, these deviations are not unexpected. The triton ranges of ref. (16) agree to about 1% with Table 2.

Burkig and MacKenzie's range measurement[22] at 18.00 MeV agrees to 0.05 mg cm^{-2} with the Al range table. The Princeton range data[7] agree with the table to 0.3% above 3.5 MeV.

It should be pointed out that the shell corrections used here do not appear to decrease fast enough for Al data (see fig. 4 of ref. (23)). A shift of the peak of the K-shell correction to lower energies might improve the situation somewhat.

2.5. Practical use of the tables

A list comparing thickness of silicon in different units is given in Table 3.

Monoenergetic particles of initial kinetic energy E will emerge from an absorber of thickness $\underline{\Delta}$ with a mean energy $\langle E_1 \rangle$ given by

$$\underline{\Delta} = \int_{\langle E_1 \rangle}^{E} (1/S)dE \; . \qquad (5)$$

For most practical purposes, a csda-range table giving R as a function of E can be used to determine $\langle E_1 \rangle$: first, the mean residual range $R(\langle E_1 \rangle)$ is determined from

$$R(\langle E_1 \rangle) = R(E) - \underline{\Delta}$$

and $\langle E_1 \rangle$ is obtained by interpolation from the table.

In applications using computers this method requires table look up. This is simple if the argument (here the energy E) shows a regular spacing, permitting selection of necessary locations with integer algebra. See Table 4 for an example.

If the energy difference $E - \langle E_1 \rangle$ is small enough, the mean value theorem can be used and

$$E - \langle E_1 \rangle = \Delta \cdot S(E') \tag{6}$$

where $S(E')$ is the stopping power at an energy $E' \sim (E + \langle E_1 \rangle)/2$. This method requires successive approximations and thus is not very suitable for practical applications.

A third method is useful if an approximation formula is given for the stopping power and the range (see Table 5):

$$S = C \cdot E^{\alpha} \tag{7}$$

$$\Delta R = C_R \, (E^{\beta} - E_1^{\beta}) \tag{8}$$

where $\beta = 1 - \alpha$ and $C_R = 1/(C \cdot \beta)$. The mean residual energy then is obtained analytically:

$$\langle E_1 \rangle = (E^{\beta} - \Delta/C_R)^{1/\beta} \tag{9}$$

If a digital computer is used to analyze pulses from an identifier system giving pulseheights in discrete channels proportional to the particle energy, it will be useful to generate range tables for energies corresponding to the value of the energy for the center of each channel. The residual range RX for a particle having a total energy producing a pulse in channel J then is simply RX(J).

3. Useful Data for Particle-Identifier Applications

Many articles describing analog-particle identifiers based on the use of eqs. (7) and (8) have appeared (e.g. refs. (25 and 26)). In order to achieve a better understanding of the approximations involved, the following functions derived from Tables 1 and 2 are given here:

a) The quantity $q = R/E^{1.76}$ is plotted in fig. 2.

b) The quantity $\gamma = \frac{\ln[R(E)/0.763 \cdot R\ (1\ \mathrm{MeV})]}{\ln E}$ is plotted in fig. 3.

c) The values C, α and C_R = CRL evaluated from eq. (7) are given in Table 5 for energy intervals from E_1 = LOWER E to E_2 = UPPER E such that the maximum deviation from Table 1 does not exceed about 0.1, 0.3, 0.6 or 1%. The actual deviation at the center point of the tabular entries is given in % under MAX.DEV.

d) Since the resolution of an identifier systems depends on the ratio of the straggling width σ to the mean energy loss, the quantity $\zeta = \sigma/(E - \langle E_1 \rangle)$ is plotted versus E_1/E for protons of initial energies E = 10, 30 and 100 MeV in fig. 4.

e) For the particle pairs (d,p), (t,d), (He^3,t) and (He^4,He^3) the ratio r of their energy losses $r = (E - \langle E_1 \rangle)_x / (E - \langle E_1 \rangle)_y$ is plotted as a function of E for detectors of thicknesses Δ = 20 mg cm^{-2}, Δ = 50 mg cm^{-2}, in fig. 5 and for Δ = 100 mg cm^{-2} and Δ = 500 mg cm^{-2} in fig. 6

f) The "particle characteristic" $E^{1.76} - \langle E_1 \rangle^{1.76}$ (fig. 2a of ref. (26)) is given by a suitable average of q of fig. 2 over the range $\langle E_1 \rangle$ to E.

g) The relative stopping power of Al (based on I = 166 eV) and Si is given in fig. 7.

4. Some Comments about Energy Measurements in Silicon Detectors

A number of details have to be considered if an energy determination in silicon detectors is desired to an accuracy of better than 1%.

Obviously, corrections have to be applied for the energy loss in the entrance window. A practical way to determine its thickness is to measure the change in pulseheight of natural α particles as a function of the angle of incidence of the particles.

The energy ϵ for the formation of an electron hole pair increases for particles of low velocities. For more energetic particles this effect can be lumped together into an ionization defect. This means that particles will seem to deposit less energy than they actually possess. An estimate of the effect[27]) indicates that the observed energy will have to be increased by about $6 \cdot M$ keV where M is the particle mass in amu. The effect is not easy to determine because it is obscured by losses due to incomplete charge collection and other effects[28]). Contradictory results are obtained by Siffert et al[29]) and by Ewing[30]).

For protons of energies from 3 to 18 MeV, pulseheight and energy in a 2-mm Li-drift-silicon detector were observed to be proportional to better than ± 5 keV after correction for entrance window and ionization defect[11]). At 20 MeV in a 3-mm detector, the pulseheight was reduced by about 1% due to pulse rise time problems.

A definite dependence of ϵ on temperature and also a difference in ϵ for electrons and α particles has been found[31]). A difference in ϵ for protons and α particles has been observed at the University of

Southern California by the authors, but further experimentation will be necessary to test all possible sources of systematic error.

An extensive discussion of counter resolution and associated problems is given in ref. (32).

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List of Tables

Figure Captions

1. Multiple scattering correction for mean ranges of protons in Si. An observed projected median range (corrected for nuclear absorption) has to be increased by ΔR to give mean range.
2. The quotient $q = R/E^{1.76}$ for six particles. Note the strong dependence of q on the value of γ for protons: for $\gamma = 1.76$, q changes by ±1% from 6.5 to 65 MeV, while for $\gamma = 1.72$, the same change occurs between 3.2 and 18 MeV.
3. The exponent γ in the approximate expression $R(E) = C_R \cdot E^{\gamma}$ where C_R is a constant chosen to be R(1 MeV)*0.763. This produces $\gamma = 1.76$ at about 40 MeV for protons and gives approximately the smallest change in γ for protons from about 7 to 200 MeV.
4. The straggling parameter σ as a function of the mean energy loss $\Delta E = E - \langle E_1 \rangle$. Plotted is the fraction $\sigma/\Delta E$ versus the residual energy $\langle E_1 \rangle$ expressed as a fraction of the initial energy for E = 10 MeV and E = 100 MeV.

Figure Captions (cont'd)

5 + 6. The ratio r of the energy loss of two particles x,y in different thicknesses of silicon absorbers: $r = (E - \langle E_1 \rangle)_x / (E - \langle E_1 \rangle)_y$.

7. Relative stopping power of Si and Al. Plotted is $S_r = (S_{Si}/S_{Al}) - 1$ in percent for 5 particles.

Table 1.

STOPPING POWER IN MEV.SQCM/GM FOR SILICON   Z= 14 A= 28.086 I= 173.5

E(MEV)	P	D	T	HE 3	HE 4	LI 7
1.00	174.902	256.298	302.610	1183.209	1224.494	1870.058
1.10	165.072	244.187	291.546	1156.467	1211.196	1893.188
1.20	156.418	233.336	281.238	1118.590	1200.907	1913.675
1.30	148.741	223.585	271.825	1083.332	1186.984	1942.589
1.40	141.866	214.715	265.028	1052.493	1174.378	1964.550
1.50	135.680	206.654	256.091	1023.798	1144.776	1963.405
1.60	130.074	199.255	247.847	991.295	1116.573	1956.030
1.70	124.969	192.440	240.251	960.909	1089.794	1946.316
1.80	120.298	186.134	233.137	932.455	1065.739	1934.883
1.90	116.006	180.289	226.535	906.050	1043.222	1933.278
2.00	112.048	174.850	220.344	881.286	1021.891	1930.895
2.10	108.382	169.776	214.526	858.015	996.904	1927.222
2.20	104.982	165.021	209.077	836.219	973.550	1922.547
2.30	101.816	160.560	203.934	815.648	951.332	1902.113
2.40	98.859	156.369	199.073	796.207	930.182	1880.232
2.50	96.091	152.420	194.472	777.803	910.254	1862.314
2.60	93.494	148.694	190.108	760.350	891.262	1844.916
2.70	91.051	145.164	185.959	743.755	873.132	1827.693
2.80	88.748	141.821	182.015	727.977	855.850	1810.699
2.90	86.573	138.650	178.263	712.971	839.407	1793.971
3.00	84.515	135.636	174.682	698.650	823.665	1777.537
3.10	82.566	132.768	171.265	684.984	808.583	1762.768
3.20	80.717	130.031	167.992	671.889	794.126	1749.186
3.30	78.959	127.422	164.859	659.362	780.251	1739.309
3.40	77.285	124.928	161.858	647.356	766.923	1729.595
3.50	75.690	122.543	158.974	635.822	754.098	1720.013
3.60	74.168	120.258	156.214	624.781	741.752	1710.571
3.70	72.715	118.068	153.557	614.156	729.866	1701.809
3.80	71.325	115.967	151.002	603.936	718.429	1693.280
3.90	69.993	113.949	148.543	594.103	707.383	1684.886
4.00	68.717	112.010	146.170	584.608	696.726	1676.634
4.20	66.316	108.346	141.675	566.631	676.473	1660.556
4.40	64.098	104.946	137.487	549.883	657.508	1643.923
4.60	62.042	101.781	133.568	534.208	639.704	1624.916
4.80	60.135	98.825	129.895	519.514	622.996	1606.689
5.00	58.349	96.058	126.444	505.712	607.239	1589.405
5.20	56.680	93.462	123.196	492.722	592.373	1572.889
5.40	55.114	91.019	120.130	480.458	578.295	1557.033
5.60	53.642	88.717	117.231	468.866	564.959	1541.818
5.80	52.257	86.542	114.489	457.897	552.320	1522.427
6.00	50.951	84.486	111.888	447.495	540.297	1501.768
6.20	49.717	82.537	109.417	437.612	528.862	1481.907
6.40	48.548	80.688	107.067	428.213	517.948	1462.831
6.60	47.439	78.931	104.831	419.270	507.543	1444.522
6.80	46.386	77.257	102.698	410.740	497.601	1426.896
7.00	45.385	75.662	100.662	402.595	488.091	1409.919

E(MEV)	P	D	T	HE 3	HE 4	LI 7
7.00	45.385	75.662	100.662	402.595	488.091	1409.919
7.20	44.431	74.142	98.715	394.809	478.985	1393.568
7.40	43.521	72.689	96.853	387.360	470.250	1377.744
7.60	42.652	71.299	95.068	380.223	461.878	1362.466
7.80	41.821	69.968	93.357	373.379	453.832	1347.721
8.00	41.026	68.692	91.714	366.806	446.100	1333.419
8.20	40.264	67.468	90.135	360.491	438.660	1319.588
8.40	39.533	66.292	88.616	354.418	431.494	1306.250
8.60	38.831	65.162	87.155	348.573	424.601	1293.289
8.80	38.156	64.075	85.747	342.942	417.949	1280.725
9.00	37.508	63.029	84.390	337.513	411.532	1265.955
9.20	36.883	62.020	83.080	332.276	405.332	1250.702
9.40	36.281	61.047	81.817	327.222	399.343	1235.909
9.60	35.701	60.113	80.596	322.340	393.554	1221.570
9.80	35.142	59.205	79.416	317.620	387.951	1207.624
10.00	34.602	58.328	78.274	313.053	382.529	1194.099
10.20	34.080	57.480	77.168	308.632	377.272	1180.970
10.40	33.575	56.659	76.098	304.351	372.179	1168.184
10.60	33.087	55.864	75.061	300.203	367.239	1155.745
10.80	32.615	55.093	74.056	296.184	362.445	1143.552
11.00	32.157	54.346	73.081	292.285	357.792	1131.528
11.20	31.714	53.622	72.136	288.503	353.272	1119.816
11.40	31.284	52.920	71.217	284.828	348.880	1108.417
11.60	30.866	52.238	70.324	281.257	344.608	1097.302
11.80	30.461	51.575	69.456	277.786	340.455	1086.464
12.00	30.068	50.932	68.613	274.413	336.414	1075.902
12.20	29.687	50.307	67.791	271.128	332.480	1065.587
12.40	29.316	49.699	66.992	267.932	328.651	1055.515
12.60	28.955	49.106	66.214	264.821	324.919	1045.689
12.80	28.604	48.530	65.457	261.792	321.284	1036.002
13.00	28.262	47.969	64.719	258.841	317.739	1026.226
13.20	27.930	47.421	64.000	255.964	314.282	1016.685
13.40	27.606	46.888	63.299	253.160	310.908	1007.356
13.60	27.290	46.368	62.615	250.424	307.615	998.231
13.80	26.982	45.862	61.947	247.753	304.401	989.313
14.00	26.683	45.368	61.295	245.147	301.262	980.583
14.20	26.390	44.885	60.664	242.624	298.198	972.037
14.40	26.105	44.414	60.042	240.135	295.204	963.678
14.60	25.826	43.954	59.434	237.704	292.279	955.489
14.80	25.554	43.504	58.840	235.326	289.418	947.471
15.00	25.289	43.065	58.259	233.003	286.620	939.630
15.50	24.651	42.009	56.862	227.416	279.884	920.698
16.00	24.048	41.010	55.538	222.122	273.497	902.680
16.50	23.477	40.063	54.282	217.097	267.430	885.512
17.00	22.936	39.163	53.089	212.324	261.663	869.140
17.50	22.423	38.308	51.953	207.783	256.172	853.297

STOPPING POWER IN MEV.SQCM/GM FOR SILICON   Z= 14   A= 28.086   I= 173.5

E(MEV)	P	D	T	HE 3	HE 4	LI 7
17.50	22.423	38.308	51.953	207.783	256.172	853.297
18.00	21.934	37.493	50.872	203.458	250.937	837.499
18.50	21.469	36.717	49.840	199.331	245.938	822.376
19.00	21.025	35.975	48.854	195.388	241.179	807.887
19.50	20.601	35.267	47.911	191.617	236.600	793.990
20.00	20.197	34.589	47.008	188.004	232.214	780.647
20.50	19.809	33.939	46.142	184.544	228.008	767.822
21.00	19.438	33.316	45.313	181.226	223.970	755.487
21.50	19.083	32.719	44.516	178.038	220.089	743.615
22.00	18.741	32.145	43.750	174.975	216.356	732.180
22.50	18.413	31.593	43.013	172.028	212.766	721.156
23.00	18.098	31.062	42.304	169.190	209.308	710.190
23.50	17.795	30.550	41.620	166.455	205.973	699.313
24.00	17.503	30.057	40.960	163.818	202.761	688.809
24.50	17.222	29.582	40.324	161.274	199.658	678.657
25.00	16.950	29.123	39.710	158.816	196.660	668.846
25.50	16.689	28.680	39.116	156.440	193.762	659.355
26.00	16.436	28.251	38.541	154.143	190.958	650.165
26.50	16.192	27.837	37.986	151.921	188.242	641.257
27.00	15.956	27.436	37.448	149.769	185.613	632.621
27.50	15.727	27.048	36.926	147.684	183.068	624.246
28.00	15.506	26.672	36.421	145.663	180.600	616.118
28.50	15.292	26.308	35.931	143.702	178.205	608.225
29.00	15.085	25.955	35.456	141.802	175.880	600.558
29.50	14.883	25.612	34.994	139.958	173.625	593.108
30.00	14.688	25.279	34.546	138.165	171.432	585.867
30.50	14.499	24.955	34.111	136.424	169.301	578.825
31.00	14.315	24.641	33.687	134.730	167.227	571.974
31.50	14.136	24.336	33.275	133.082	165.210	565.302
32.00	13.962	24.038	32.875	131.480	163.249	558.804
32.50	13.793	23.749	32.485	129.921	161.338	552.474
33.00	13.629	23.468	32.105	128.403	159.477	546.352
33.50	13.469	23.194	31.735	126.923	157.663	540.330
34.00	13.314	22.927	31.375	125.481	155.894	534.455
34.50	13.162	22.667	31.023	124.075	154.170	528.720
35.00	13.014	22.414	30.680	122.704	152.488	523.128
35.50	12.871	22.167	30.346	121.366	150.847	517.667
36.00	12.730	21.925	30.020	120.061	149.245	512.333
36.50	12.594	21.690	29.701	118.788	147.680	507.119
37.00	12.460	21.460	29.391	117.545	146.152	502.026
37.50	12.330	21.236	29.087	116.331	144.658	497.045
38.00	12.203	21.017	28.790	115.144	143.199	492.174
38.50	12.079	20.803	28.500	113.984	141.773	487.408
39.00	11.957	20.593	28.216	112.849	140.379	482.748
39.50	11.839	20.389	27.939	111.740	139.015	478.191
40.00	11.723	20.189	27.668	110.654	137.680	473.728

E(MEV)	P	D	T	HE 3	HE 4	LI 7
40.00	11.723	20.189	27.668	110.654	137.680	473.728
40.50	11.610	19.993	27.402	109.592	136.373	469.358
41.00	11.499	19.802	27.142	108.553	135.094	465.076
41.50	11.391	19.614	26.888	107.537	133.841	460.887
42.00	11.285	19.431	26.639	106.541	132.613	456.784
42.50	11.181	19.251	26.395	105.566	131.412	452.761
43.00	11.079	19.075	26.156	104.611	130.235	448.815
43.50	10.980	18.903	25.922	103.674	129.081	444.947
44.00	10.883	18.734	25.693	102.757	127.949	441.152
44.50	10.787	18.568	25.468	101.857	126.840	437.431
45.00	10.694	18.406	25.247	100.975	125.751	433.779
45.50	10.602	18.247	25.031	100.109	124.684	430.195
46.00	10.513	18.091	24.819	99.260	123.636	426.676
46.50	10.425	17.938	24.610	98.427	122.608	423.220
47.00	10.338	17.788	24.406	97.610	121.598	419.826
47.50	10.254	17.641	24.205	96.807	120.608	416.498
48.00	10.171	17.496	24.008	96.019	119.636	413.231
48.50	10.089	17.354	23.815	95.246	118.682	410.020
49.00	10.009	17.215	23.625	94.487	117.744	406.864
49.50	9.931	17.078	23.439	93.742	116.823	403.761
50.00	9.854	16.944	23.256	93.009	115.918	400.711
51.00	9.704	16.682	22.899	91.582	114.154	394.764
52.00	9.560	16.430	22.554	90.203	112.448	389.016
53.00	9.420	16.186	22.221	88.869	110.799	383.451
54.00	9.285	15.950	21.898	87.579	109.203	378.060
55.00	9.155	15.721	21.586	86.331	107.658	372.836
56.00	9.028	15.500	21.283	85.121	106.162	367.776
57.00	8.906	15.286	20.990	83.949	104.712	362.867
58.00	8.788	15.079	20.706	82.813	103.305	358.102
59.00	8.673	14.878	20.431	81.711	101.940	353.473
60.00	8.562	14.682	20.163	80.641	100.614	348.976
61.00	8.454	14.493	19.904	79.603	99.327	344.609
62.00	8.350	14.309	19.651	78.594	98.076	340.363
63.00	8.248	14.130	19.406	77.614	96.859	336.231
64.00	8.150	13.957	19.168	76.660	95.676	332.209
65.00	8.054	13.788	18.936	75.733	94.526	328.293
66.00	7.961	13.624	18.710	74.831	93.407	324.479
67.00	7.870	13.464	18.491	73.952	92.316	320.766
68.00	7.782	13.308	18.277	73.097	91.254	317.148
69.00	7.696	13.157	18.068	72.263	90.219	313.620
70.00	7.613	13.009	17.865	71.451	89.210	310.177
71.00	7.532	12.866	17.667	70.659	88.226	306.818
72.00	7.452	12.725	17.474	69.886	87.265	303.539
73.00	7.375	12.589	17.286	69.133	86.328	300.337
74.00	7.300	12.455	17.102	68.398	85.414	297.211
75.00	7.226	12.325	16.923	67.680	84.520	294.158

STOPPING POWER IN MEV.SQCM/GM FOR SILICON

Z= 14 A= 28.086 I= 173.5

E(MEV)	P	D	T	HE 3	HE 4	LI 7
75.00	7.226	12.325	16.923	67.680	84.520	294.158
76.00	7.155	12.198	16.747	66.980	83.648	291.174
77.00	7.085	12.074	16.576	66.295	82.795	288.257
78.00	7.016	11.953	16.409	65.627	81.962	285.405
79.00	6.950	11.834	16.246	64.973	81.148	282.614
80.00	6.885	11.718	16.086	64.334	80.352	279.884
81.00	6.821	11.605	15.930	63.709	79.573	277.212
82.00	6.759	11.495	15.777	63.098	78.811	274.596
83.00	6.698	11.386	15.627	62.500	78.065	272.034
84.00	6.638	11.280	15.481	61.914	77.335	269.529
85.00	6.580	11.177	15.338	61.341	76.620	267.076
86.00	6.523	11.075	15.197	60.780	75.920	264.671
87.00	6.467	10.976	15.060	60.230	75.234	262.315
88.00	6.413	10.879	14.925	59.692	74.561	260.004
89.00	6.359	10.783	14.793	59.164	73.903	257.739
90.00	6.307	10.690	14.664	58.647	73.257	255.517
91.00	6.256	10.598	14.537	58.141	72.624	253.337
92.00	6.206	10.509	14.413	57.644	72.003	251.199
93.00	6.157	10.421	14.291	57.156	71.394	249.101
94.00	6.108	10.334	14.172	56.678	70.796	247.041
95.00	6.061	10.250	14.054	56.209	70.210	245.019
96.00	6.015	10.167	13.939	55.749	69.635	243.035
97.00	5.969	10.085	13.826	55.297	69.070	241.088
98.00	5.925	10.005	13.715	54.854	68.516	239.175
99.00	5.881	9.927	13.607	54.419	67.971	237.296
100.00	5.838	9.850	13.500	53.991	67.437	235.449
101.00	5.796	9.774	13.395	53.572	66.912	233.634
102.00	5.754	9.701	13.292	53.159	66.396	231.851
103.00	5.714	9.628	13.190	52.754	65.889	230.097
104.00	5.674	9.556	13.091	52.356	65.390	228.373
105.00	5.635	9.486	12.993	51.965	64.901	226.677
106.00	5.596	9.416	12.897	51.580	64.419	225.010
107.00	5.558	9.348	12.802	51.202	63.945	223.369
108.00	5.521	9.282	12.709	50.830	63.480	221.755
109.00	5.485	9.216	12.618	50.465	63.022	220.167
110.00	5.449	9.151	12.528	50.105	62.571	218.604
111.00	5.413	9.087	12.440	49.751	62.128	217.066
112.00	5.379	9.025	12.353	49.403	61.691	215.553
113.00	5.344	8.963	12.267	49.061	61.262	214.064
114.00	5.311	8.903	12.183	48.724	60.839	212.597
115.00	5.278	8.843	12.100	48.392	60.423	211.153
116.00	5.245	8.785	12.018	48.065	60.014	209.731
117.00	5.213	8.727	11.938	47.744	59.610	208.330
118.00	5.182	8.670	11.858	47.427	59.213	206.950
119.00	5.151	8.614	11.781	47.115	58.822	205.590
120.00	5.120	8.559	11.704	46.808	58.436	204.250

E(MEV)	P	D	T	HE 3	HE 4	LI 7
120.00	5.120	8.559	11.704	46.808	58.436	204.250
122.00	5.061	8.451	11.554	46.208	57.683	201.628
124.00	5.003	8.347	11.408	45.625	56.951	199.081
126.00	4.947	8.245	11.266	45.058	56.240	196.604
128.00	4.893	8.147	11.129	44.508	55.548	194.196
130.00	4.840	8.051	10.995	43.974	54.877	191.853
132.00	4.789	7.958	10.865	43.454	54.223	189.572
134.00	4.739	7.867	10.738	42.948	53.587	187.351
136.00	4.690	7.779	10.615	42.455	52.968	185.189
138.00	4.643	7.694	10.496	41.976	52.366	183.082
140.00	4.597	7.610	10.379	41.509	51.778	181.029
142.00	4.552	7.529	10.265	41.054	51.206	179.027
144.00	4.509	7.450	10.154	40.611	50.648	177.073
146.00	4.467	7.372	10.046	40.178	50.104	175.167
148.00	4.425	7.297	9.941	39.757	49.573	173.307
150.00	4.385	7.224	9.838	39.345	49.055	171.491
152.00	4.346	7.152	9.738	38.946	48.549	169.717
154.00	4.308	7.082	9.640	38.554	48.055	167.984
156.00	4.270	7.014	9.544	38.171	47.573	166.290
158.00	4.234	6.947	9.451	37.797	47.101	164.634
160.00	4.198	6.882	9.359	37.432	46.641	163.016
162.00	4.164	6.818	9.270	37.075	46.190	161.432
164.00	4.130	6.756	9.183	36.726	45.750	159.883
166.00	4.097	6.695	9.097	36.384	45.319	158.368
168.00	4.064	6.636	9.014	36.050	44.897	156.884
170.00	4.033	6.578	8.932	35.723	44.485	155.432
172.00	4.002	6.521	8.852	35.403	44.081	154.010
174.00	3.971	6.465	8.774	35.090	43.686	152.618
176.00	3.942	6.411	8.697	34.783	43.299	151.254
178.00	3.913	6.357	8.622	34.483	42.919	149.917
180.00	3.884	6.305	8.548	34.189	42.548	148.607
182.00	3.857	6.254	8.476	33.901	42.183	147.322
184.00	3.829	6.203	8.406	33.618	41.826	146.062
186.00	3.803	6.154	8.337	33.341	41.476	144.827
188.00	3.777	6.106	8.269	33.070	41.133	143.615
190.00	3.751	6.059	8.202	32.804	40.797	142.425
192.00	3.726	6.012	8.137	32.542	40.466	141.258
194.00	3.701	5.967	8.073	32.286	40.142	140.113
196.00	3.677	5.922	8.010	32.035	39.824	138.988
198.00	3.654	5.879	7.948	31.788	39.512	137.884
200.00	3.631	5.836	7.888	31.546	39.206	136.799

Table 2.

RANGES IN GM/SQCM FOR SILICON   Z= 14 A= 28.086 I= 173.5

E(MEV)	P	D	T	HE 3	HE 4	LI 7
1.00	.003800	.002860	.002550	.001030	.000960	.000750
1.10	.004389	.003260	.002887	.001115	.001042	.000803
1.20	.005011	.003679	.003236	.001203	.001125	.000856
1.30	.005667	.004117	.003598	.001294	.001209	.000908
1.40	.006356	.004573	.003969	.001388	.001294	.000959
1.50	.007077	.005048	.004353	.001484	.001380	.001010
1.60	.007830	.005541	.004750	.001583	.001468	.001061
1.70	.008614	.006052	.005160	.001686	.001559	.001112
1.80	.009430	.006580	.005582	.001791	.001652	.001163
1.90	.010277	.007126	.006018	.001900	.001747	.001215
2.00	.011154	.007690	.006465	.002012	.001843	.001267
2.10	.012062	.008270	.006925	.002127	.001943	.001319
2.20	.012999	.008868	.007398	.002245	.002044	.001371
2.30	.013967	.009482	.007882	.002366	.002148	.001423
2.40	.014964	.010113	.008378	.002490	.002254	.001476
2.50	.015990	.010761	.008887	.002618	.002363	.001529
2.60	.017045	.011425	.009407	.002748	.002474	.001583
2.70	.018129	.012106	.009939	.002881	.002587	.001638
2.80	.019241	.012803	.010482	.003016	.002703	.001693
2.90	.020382	.013516	.011037	.003155	.002821	.001748
3.00	.021551	.014246	.011604	.003297	.002941	.001804
3.10	.022749	.014991	.012182	.003442	.003064	.001861
3.20	.023974	.015752	.012772	.003589	.003189	.001918
3.30	.025226	.016529	.013373	.003739	.003316	.001975
3.40	.026507	.017321	.013985	.003892	.003445	.002033
3.50	.027814	.018130	.014608	.004048	.003577	.002091
3.60	.029149	.018954	.015243	.004207	.003710	.002149
3.70	.030511	.019793	.015889	.004368	.003846	.002207
3.80	.031899	.020647	.016545	.004532	.003984	.002266
3.90	.033315	.021517	.017213	.004699	.004125	.002326
4.00	.034757	.022403	.017892	.004869	.004267	.002385
4.20	.037720	.024218	.019282	.005217	.004558	.002505
4.40	.040788	.026094	.020715	.005575	.004858	.002626
4.60	.043960	.028030	.022191	.005944	.005167	.002748
4.80	.047235	.030024	.023710	.006324	.005484	.002872
5.00	.050612	.032077	.025270	.006714	.005809	.002997
5.20	.054090	.034188	.026873	.007115	.006142	.003124
5.40	.057669	.036357	.028517	.007526	.006484	.003252
5.60	.061347	.038583	.030203	.007947	.006834	.003381
5.80	.065125	.040865	.031929	.008379	.007192	.003511
6.00	.069002	.043205	.033696	.008821	.007558	.003643
6.20	.072976	.045600	.035504	.009273	.007932	.003777
6.40	.077047	.048051	.037352	.009735	.008314	.003913
6.60	.081215	.050557	.039240	.010207	.008705	.004051
6.80	.085479	.053118	.041168	.010689	.009103	.004190
7.00	.089838	.055734	.043135	.011181	.009508	.004331

E(MEV)	P	D	T	HE 3	HE 4	LI 7
7.00	.089838	.055734	.043135	.011181	.009508	.004331
7.20	.094292	.058405	.045141	.011682	.009922	.004474
7.40	.098841	.061129	.047187	.012194	.010343	.004618
7.60	.103483	.063908	.049271	.012715	.010773	.004764
7.80	.108219	.066739	.051394	.013246	.011209	.004912
8.00	.113047	.069624	.053556	.013786	.011654	.005061
8.20	.117969	.072562	.055756	.014336	.012106	.005212
8.40	.122982	.075553	.057993	.014896	.012566	.005364
8.60	.128087	.078596	.060269	.015465	.013033	.005518
8.80	.133283	.081692	.062583	.016043	.013508	.005673
9.00	.138570	.084839	.064934	.016631	.013990	.005830
9.20	.143947	.088038	.067323	.017228	.014480	.005989
9.40	.149415	.091288	.069749	.017835	.014977	.006150
9.60	.154972	.094590	.072212	.018451	.015481	.006313
9.80	.160619	.097942	.074712	.019076	.015993	.006478
10.00	.166354	.101346	.077248	.019710	.016513	.006644
10.20	.172179	.104800	.079822	.020354	.017039	.006813
10.40	.178091	.108305	.082432	.021006	.017573	.006983
10.60	.184092	.111860	.085078	.021668	.018114	.007155
10.80	.190180	.115465	.087761	.022339	.018662	.007329
11.00	.196356	.119120	.090480	.023018	.019217	.007505
11.20	.202619	.122825	.093234	.023707	.019780	.007683
11.40	.208969	.126580	.096025	.024405	.020350	.007862
11.60	.215405	.130384	.098851	.025112	.020926	.008043
11.80	.221928	.134237	.101713	.025827	.021510	.008227
12.00	.228537	.138139	.104610	.026551	.022101	.008412
12.20	.235231	.142091	.107542	.027285	.022699	.008598
12.40	.242011	.146090	.110510	.028027	.023304	.008787
12.60	.248875	.150139	.113513	.028778	.023916	.008977
12.80	.255825	.154236	.116551	.029537	.024535	.009169
13.00	.262859	.158381	.119624	.030306	.025161	.009363
13.20	.269978	.162575	.122732	.031083	.025794	.009559
13.40	.277181	.166816	.125874	.031868	.026434	.009757
13.60	.284468	.171106	.129051	.032663	.027081	.009956
13.80	.291838	.175443	.132262	.033466	.027735	.010158
14.00	.299292	.179827	.135508	.034277	.028395	.010361
14.20	.306829	.184260	.138788	.035097	.029062	.010566
14.40	.314449	.188739	.142102	.035926	.029736	.010772
14.60	.322152	.193266	.145450	.036763	.030417	.010981
14.80	.329937	.197839	.148832	.037609	.031105	.011191
15.00	.337805	.202460	.152248	.038463	.031799	.011403
15.50	.357833	.214216	.160936	.040635	.033565	.011940
16.00	.378371	.226264	.169834	.042860	.035372	.012489
16.50	.399416	.238600	.178941	.045137	.037221	.013048
17.00	.420964	.251224	.188256	.047466	.039111	.013618
17.50	.443014	.264134	.197777	.049847	.041043	.014199

RANGES IN GM/SQCM FOR SILICON

Z= 14 A= 28.086 I= 173.5

E(MEV)	P	D	T	HE 3	HE 4	LI 7
17.50	.443014	.264134	.197777	.049847	.041043	.014199
18.00	.465561	.277328	.207504	.052279	.043015	.014790
18.50	.488604	.290805	.217434	.054762	.045028	.015393
19.00	.512140	.304563	.227568	.057295	.047081	.016006
19.50	.536166	.318601	.237903	.059879	.049174	.016630
20.00	.560680	.332918	.248439	.062514	.051307	.017266
20.50	.585679	.347512	.259176	.065198	.053480	.017911
21.00	.611161	.362382	.270111	.067933	.055693	.018568
21.50	.637123	.377527	.281244	.070716	.057945	.019235
22.00	.663564	.392945	.292575	.073549	.060236	.019913
22.50	.690480	.408635	.304101	.076431	.062567	.020601
23.00	.717871	.424597	.315823	.079362	.064936	.021299
23.50	.745734	.440829	.327740	.082342	.067345	.022009
24.00	.774066	.457330	.339850	.085370	.069791	.022729
24.50	.802866	.474099	.352153	.088446	.072276	.023461
25.00	.832132	.491135	.364649	.091570	.074800	.024203
25.50	.861861	.508436	.377336	.094743	.077361	.024956
26.00	.892052	.526002	.390214	.097963	.079961	.025719
26.50	.922702	.543832	.403282	.101230	.082598	.026494
27.00	.953810	.561925	.416539	.104545	.085273	.027279
27.50	.985374	.580280	.429985	.107907	.087986	.028075
28.00	1.017393	.598896	.443620	.111316	.090735	.028881
28.50	1.049863	.617772	.457442	.114772	.093523	.029698
29.00	1.082785	.636907	.471451	.118275	.096347	.030525
29.50	1.116155	.656300	.485646	.121824	.099208	.031363
30.00	1.149973	.675951	.500027	.125420	.102106	.032211
30.50	1.184237	.695859	.514592	.129062	.105041	.033070
31.00	1.218944	.716022	.529343	.132750	.108013	.033939
31.50	1.254094	.736441	.544277	.136484	.111021	.034818
32.00	1.289685	.757114	.559395	.140264	.114066	.035708
32.50	1.325715	.778041	.574695	.144090	.117147	.036607
33.00	1.362183	.799220	.590178	.147961	.120264	.037518
33.50	1.399087	.820652	.605843	.151878	.123417	.038438
34.00	1.436426	.842334	.621688	.155840	.126607	.039368
34.50	1.474198	.864267	.637715	.159847	.129832	.040309
35.00	1.512401	.886450	.653922	.163899	.133093	.041260
35.50	1.551035	.908882	.670309	.167997	.136390	.042220
36.00	1.590097	.931563	.686875	.172139	.139722	.043191
36.50	1.629587	.954491	.703621	.176326	.143090	.044172
37.00	1.669502	.977666	.720544	.180557	.146493	.045163
37.50	1.709843	1.001088	.737645	.184833	.149932	.046164
38.00	1.750606	1.024756	.754923	.189153	.153406	.047175
38.50	1.791791	1.048669	.772379	.193518	.156916	.048196
39.00	1.833397	1.072827	.790011	.197926	.160460	.049227
39.50	1.875422	1.097229	.807819	.202379	.164039	.050267
40.00	1.917865	1.121874	.825803	.206876	.167653	.051318
40.00	1.917865	1.121874	.825803	.206876	.167653	.051318
40.50	1.960725	1.146761	.843962	.211416	.171302	.052378
41.00	2.004000	1.171891	.862296	.216000	.174986	.053449
41.50	2.047689	1.197262	.880805	.220628	.178705	.054529
42.00	2.091790	1.222875	.899488	.225299	.182458	.055618
42.50	2.136304	1.248727	.918344	.230014	.186245	.056718
43.00	2.181227	1.274820	.937373	.234772	.190067	.057827
43.50	2.226560	1.301151	.956575	.239573	.193924	.058946
44.00	2.272301	1.327722	.975949	.244418	.197814	.060074
44.50	2.318448	1.354530	.995496	.249305	.201739	.061213
45.00	2.365001	1.381576	1.015214	.254235	.205698	.062360
45.50	2.411959	1.408859	1.035104	.259209	.209691	.063518
46.00	2.459319	1.436379	1.055165	.264225	.213719	.064685
46.50	2.507082	1.464135	1.075396	.269283	.217780	.065862
47.00	2.555245	1.492126	1.095798	.274384	.221875	.067048
47.50	2.603808	1.520352	1.116370	.279528	.226003	.068244
48.00	2.652770	1.548813	1.137111	.284714	.230166	.069449
48.50	2.702130	1.577508	1.158022	.289942	.234362	.070664
49.00	2.751886	1.606436	1.179101	.295213	.238592	.071888
49.50	2.802037	1.635597	1.200349	.300526	.242855	.073121
50.00	2.852582	1.664990	1.221765	.305881	.247152	.074364
51.00	2.954850	1.724471	1.265100	.316716	.255845	.076879
52.00	3.058676	1.784876	1.309105	.327719	.264672	.079431
53.00	3.164058	1.846200	1.353776	.338888	.273631	.082020
54.00	3.270987	1.908441	1.399111	.350224	.282722	.084646
55.00	3.379455	1.971594	1.445107	.361725	.291945	.087310
56.00	3.489454	2.035655	1.491763	.373390	.301299	.090011
57.00	3.600976	2.100622	1.539076	.385220	.310784	.092748
58.00	3.714014	2.166491	1.587044	.397214	.320399	.095522
59.00	3.828558	2.233258	1.635665	.409371	.330144	.098333
60.00	3.944603	2.300920	1.684935	.421690	.340019	.101180
61.00	4.062140	2.369474	1.734854	.434172	.350022	.104064
62.00	4.181162	2.438916	1.785419	.446815	.360154	.106984
63.00	4.301661	2.509244	1.836627	.459619	.370414	.109940
64.00	4.423630	2.580453	1.888477	.472583	.380803	.112932
65.00	4.547063	2.652542	1.940967	.485708	.391318	.115960
66.00	4.671952	2.725506	1.994095	.498992	.401961	.119024
67.00	4.798289	2.799343	2.047859	.512435	.412730	.122124
68.00	4.926069	2.874049	2.102257	.526036	.423625	.125259
69.00	5.055284	2.949622	2.157287	.539796	.434646	.128430
70.00	5.185928	3.026059	2.212947	.553713	.445793	.131637
71.00	5.317994	3.103356	2.269235	.567787	.457065	.134878
72.00	5.451475	3.181511	2.326150	.582018	.468462	.138155
73.00	5.586365	3.260521	2.383689	.596405	.479984	.141467
74.00	5.722657	3.340383	2.441851	.610947	.491630	.144814
75.00	5.860344	3.421095	2.500634	.625645	.503399	.148196

RANGES IN GM/SQCM FOR SILICON

Z= 14 A= 28.086 I= 173.5

E(MEV)	P	D	T	HE 3	HE 4	LI 7
75.00	5.860344	3.421095	2.500634	.625645	.503399	.148196
76.00	5.999422	3.502654	2.560036	.640498	.515292	.151613
77.00	6.139882	3.585056	2.620055	.655505	.527309	.155065
78.00	6.281720	3.668300	2.680690	.670666	.539448	.158551
79.00	6.424928	3.752383	2.741938	.685980	.551710	.162073
80.00	6.569502	3.837302	2.803799	.701448	.564094	.165628
81.00	6.715434	3.923054	2.866270	.717068	.576601	.169218
82.00	6.862719	4.009637	2.929351	.732840	.589229	.172843
83.00	7.011351	4.097049	2.993038	.748765	.601978	.176502
84.00	7.161323	4.185287	3.057332	.764840	.614848	.180195
85.00	7.312631	4.274348	3.122230	.781067	.627839	.183922
86.00	7.465268	4.364230	3.187730	.797445	.640951	.187683
87.00	7.619229	4.454931	3.253832	.813973	.654183	.191479
88.00	7.774508	4.546448	3.320534	.830650	.667535	.195308
89.00	7.931100	4.638778	3.387833	.847478	.681006	.199171
90.00	8.088998	4.731920	3.455730	.864454	.694597	.203067
91.00	8.248198	4.825871	3.524221	.881580	.708307	.206998
92.00	8.408693	4.920629	3.593306	.898854	.722136	.210962
93.00	8.570479	5.016191	3.662984	.916276	.736084	.214960
94.00	8.733550	5.112555	3.733252	.933845	.750150	.218991
95.00	8.897901	5.209719	3.804110	.951563	.764334	.223056
96.00	9.063526	5.307680	3.875556	.969427	.778636	.227154
97.00	9.230420	5.406437	3.947589	.987438	.793055	.231285
98.00	9.398578	5.505987	4.020207	1.005595	.807592	.235449
99.00	9.567995	5.606328	4.093409	1.023898	.822246	.239647
100.00	9.738665	5.707458	4.167193	1.042347	.837016	.243878
101.00	9.910584	5.809374	4.241559	1.060941	.851903	.248141
102.00	10.083746	5.912069	4.316504	1.079680	.866906	.252438
103.00	10.258147	6.015545	4.392027	1.098564	.882025	.256767
104.00	10.433781	6.119801	4.468128	1.117591	.897260	.261130
105.00	10.610644	6.224835	4.544804	1.136763	.912611	.265525
106.00	10.788730	6.330646	4.622055	1.156079	.928076	.269953
107.00	10.968035	6.437230	4.699879	1.175538	.943657	.274414
108.00	11.148554	6.544586	4.778275	1.195140	.959353	.278907
109.00	11.330282	6.652711	4.857242	1.214884	.975163	.283432
110.00	11.513214	6.761605	4.936778	1.234771	.991088	.287991
111.00	11.697346	6.871264	5.016883	1.254800	1.007127	.292581
112.00	11.882672	6.981687	5.097554	1.274971	1.023280	.297204
113.00	12.069189	7.092872	5.178792	1.295284	1.039546	.301860
114.00	12.256891	7.204817	5.260593	1.315737	1.055926	.306547
115.00	12.445774	7.317519	5.342959	1.336331	1.072420	.311267
116.00	12.635833	7.430977	5.425886	1.357066	1.089026	.316019
117.00	12.827064	7.545190	5.509375	1.377942	1.105745	.320803
118.00	13.019463	7.660154	5.593423	1.398957	1.122577	.325619
119.00	13.213024	7.775869	5.678030	1.420112	1.139522	.330467
120.00	13.407743	7.892332	5.763194	1.441406	1.156578	.335347

E(MEV)	P	D	T	HE 3	HE 4	LI 7
120.00	13.407743	7.892332	5.763194	1.441406	1.156578	.335347
122.00	13.800639	8.127495	5.935191	1.484411	1.191027	.345203
124.00	14.198116	8.365629	6.109404	1.527971	1.225923	.355186
126.00	14.600138	8.606718	6.285824	1.572083	1.261263	.365295
128.00	15.006671	8.850750	6.464443	1.616744	1.297047	.375531
130.00	15.417682	9.097709	6.645252	1.661953	1.333272	.385893
132.00	15.833138	9.347580	6.828242	1.707707	1.369937	.396380
134.00	16.253004	9.600351	7.013404	1.754004	1.407040	.406993
136.00	16.677249	9.856008	7.200731	1.800843	1.444581	.417730
138.00	17.105841	10.114535	7.390213	1.848220	1.482557	.428592
140.00	17.538747	10.375921	7.581843	1.896135	1.520967	.439578
142.00	17.975936	10.640152	7.775612	1.944584	1.559809	.450688
144.00	18.417377	10.907214	7.971513	1.993566	1.599082	.461921
146.00	18.863040	11.177095	8.169537	2.043080	1.638785	.473278
148.00	19.312893	11.449781	8.369676	2.093122	1.678916	.484757
150.00	19.766907	11.725259	8.571924	2.143691	1.719474	.496358
152.00	20.225052	12.003518	8.776269	2.194785	1.760457	.508081
154.00	20.687298	12.284544	8.982694	2.246399	1.801865	.519926
156.00	21.153617	12.568325	9.191205	2.298534	1.843695	.531893
158.00	21.623980	12.854849	9.401792	2.351189	1.885946	.543981
160.00	22.098357	13.144103	9.614450	2.404361	1.928618	.556189
162.00	22.576722	13.436075	9.829170	2.458048	1.971708	.568518
164.00	23.059045	13.730754	10.045945	2.512250	2.015216	.580967
166.00	23.545300	14.028128	10.264767	2.566964	2.059140	.593536
168.00	24.035460	14.328184	10.485631	2.622188	2.103479	.606225
170.00	24.529496	14.630912	10.708528	2.677920	2.148231	.619033
172.00	25.027383	14.936299	10.933452	2.734159	2.193397	.631959
174.00	25.529093	15.244334	11.160396	2.790903	2.238973	.645005
176.00	26.034601	15.555007	11.389353	2.848151	2.284959	.658169
178.00	26.543881	15.868305	11.620316	2.905900	2.331354	.671450
180.00	27.056906	16.184217	11.853278	2.964149	2.378157	.684850
182.00	27.573652	16.502733	12.088233	3.022896	2.425366	.698367
184.00	28.094094	16.823842	12.325174	3.082140	2.472981	.712001
186.00	28.618205	17.147532	12.564094	3.141878	2.520999	.725753
188.00	29.145962	17.473792	12.804987	3.202110	2.569420	.739620
190.00	29.677340	17.802613	13.047847	3.262834	2.618244	.753605
192.00	30.212315	18.133984	13.292666	3.324048	2.667468	.767705
194.00	30.750862	18.467894	13.539439	3.385750	2.717091	.781922
196.00	31.292959	18.804332	13.788160	3.447939	2.767113	.796254
198.00	31.838580	19.143288	14.038822	3.510613	2.817532	.810701
200.00	32.387704	19.484753	14.291418	3.573772	2.868347	.825263

Table 3

Conversion table for thickness of monocrystalline silicon absorbers. Density used $\rho = 2.3290$ g cm^{-3} (Ref. 24)

mg cm^{-2}	mm	μ	mils = 0.001"
1	0.0043	4.294	0.169
2	0.0086	8.587	0.338
3	0.0129	12.881	0.507
4	0.0172	17.175	0.676
5	0.0215	21.468	0.845
6	0.0258	25.76	1.014
7	0.0301	30.06	1.183
8	0.0344	34.35	1.352
9	0.0386	38.64	1.521
10	0.0429	42.94	1.690
20	0.0859	85.87	3.338
40	0.1718	171.75	6.762
70	0.3006	300.6	11.83
100	0.4294	429.4	16.90
200	0.8587	858.7	33.38
400	1.7175	1717.5	67.62
700	3.006	3006.	118.3
1000	4.294	4294	169.0
2000	8.587	8587	333.8
4000	17.175	17175	676.2
7000	30.056	30056	1183
10000	42.9369	42937	1690.431

Table 4

Table lookup in a FORTRAN program.

Example: Find the range RX for a particle of energy E1 = 2.12. The following FORTRAN statements are necessary:

```
DIMENSION  R(11)
 .
 .
 .
 .
XA = E1*5.0
JX = XA - 3.99999
RX = R(JX) + (R(JX+1) - R(JX))*(XA - FLOAT(JX+4))
 .
 .
 .
```

J	E	R(J)
1	1.0	3.80
2	1.2	5.01
3	1.4	6.36
4	1.6	7.83
5	1.8	9.43
6	2.0	11.15
7	2.2	13.00
8	2.4	14.96
9	2.6	17.04
10	2.8	19.24
11	3.0	21.55

Note that it is not necessary to store E in the memory.

Table 5.

POLYNOMIAL APPROXIMATION FOR SILICON   STOPPING POWER S=C*E**ALPHA, RANGE R=CRL*E**(1-ALPHA).

PARTICLE P

LOWER E	UPPER E	ALPHA	C	MAX. DEV	CRL
ERROR= .1 0/0					
1.000	1.300	-.617530	174.902	-.1056	3.53470E-03
1.300	1.800	-.652180	176.499	-.1428	3.42925E-03
1.800	2.500	-.683931	179.824	-.1110	3.30238E-03
2.500	3.600	-.710193	184.204	-.1102	3.17435E-03
3.600	5.400	-.732328	189.502	-.1024	3.04619E-03
5.400	8.600	-.752515	196.064	-.1058	2.91032E-03
8.600	14.600	-.770541	203.818	-.1041	2.77109E-03
14.600	52.000	-.782407	210.407	.1108	2.66645E-03
52.000	77.000	-.763266	195.080	.1079	2.90716E-03
77.000	105.000	-.738363	175.079	.1056	3.28568E-03
105.000	138.000	-.708246	152.182	.1061	3.84669E-03
138.000	174.000	-.674162	128.655	.1015	4.64277E-03
174.000	200.000	-.643992	110.111	.0427	5.52422E-03
ERROR= .3 0/0					
1.000	1.600	-.630049	174.902	-.3279	3.50755E-03
1.600	2.800	-.683155	179.323	-.3237	3.31315E-03
2.800	5.600	-.726342	187.476	-.3255	3.08978E-03
5.600	12.800	-.760621	198.881	-.3015	2.85588E-03
12.800	67.000	-.779611	208.747	.3147	2.69187E-03
67.000	114.000	-.740052	176.759	.3004	3.25129E-03
114.000	174.000	-.687374	137.730	.3116	4.30289E-03
174.000	200.000	-.643992	110.111	.0427	5.52422E-03
ERROR= .6 0/0					
1.000	2.000	-.642434	174.902	-.6535	3.48110E-03
2.000	4.800	-.710855	183.397	-.6105	3.18709E-03
4.800	16.500	-.761745	198.637	-.6279	2.85757E-03
16.500	78.000	-.777539	207.630	.6003	2.70951E-03
78.000	152.000	-.717962	160.164	.6016	3.63432E-03
152.000	200.000	-.655272	116.892	.1570	5.16829E-03
ERROR= 1.0 0/0					
1.000	2.500	-.653642	174.902	-1.0302	3.45751E-03
2.500	9.000	-.734429	188.341	-1.0160	3.06126E-03
9.000	100.000	-.772518	204.781	1.0102	2.75499E-03
100.000	200.000	-.685216	136.989	.8409	4.33169E-03

PARTICLE D

LOWER E	UPPER E	ALPHA	C	MAX. DEV	CRL
ERROR= .1 0/0					
1.000	1.300	-.520459	256.298	-.1304	2.56614E-03
1.300	1.700	-.559184	258.916	-.1271	2.47710E-03
1.700	2.200	-.596165	264.047	-.1101	2.37269E-03
2.200	2.900	-.630300	271.249	-.1145	2.26133E-03
2.900	3.900	-.662246	280.634	-.1123	2.14370E-03
3.900	5.400	-.690440	291.612	-.1046	2.02859E-03
5.400	7.800	-.715280	304.087	-.1039	1.91720E-03
7.800	11.600	-.736314	317.513	-.1059	1.81388E-03
11.600	18.500	-.755371	332.696	-.1036	1.71231E-03
18.500	32.000	-.773005	350.262	-.1040	1.61027E-03
32.000	105.000	-.782572	362.071	.1040	1.54939E-03
105.000	156.000	-.762592	329.920	.1052	1.71965E-03
156.000	200.000	-.740027	294.389	.0664	1.95219E-03
ERROR= .3 0/0					
1.000	1.600	-.535653	256.298	-.3978	2.54075E-03
1.600	2.500	-.600379	264.215	-.3276	2.36494E-03
2.500	4.200	-.657904	278.515	-.3511	2.16566E-03
4.200	7.800	-.706393	298.586	-.3203	1.96269E-03
7.800	16.500	-.744207	322.703	-.3107	1.77664E-03
16.500	47.500	-.775741	352.530	-.3024	1.59744E-03
47.500	132.000	-.778857	356.796	.3157	1.57557E-03
132.000	200.000	-.746440	304.563	.1683	1.88005E-03
ERROR= .6 0/0					
1.000	1.800	-.544203	256.298	-.6060	2.52668E-03
1.800	3.500	-.628601	269.333	-.6419	2.27979E-03
3.500	8.000	-.700179	294.600	-.6140	1.99651E-03
8.000	24.000	-.752361	328.366	-.6181	1.73787E-03
24.000	164.000	-.776683	354.755	.6037	1.58658E-03
164.000	200.000	-.737936	291.146	.0436	1.97631E-03
ERROR= 1.0 0/0					
1.000	2.200	-.558391	256.298	-1.0630	2.50367E-03
2.200	5.400	-.662635	278.254	-1.0051	2.16153E-03
5.400	20.500	-.739485	316.757	-1.0267	1.81490E-03
20.500	198.000	-.773088	350.593	1.0250	1.60867E-03
198.000	200.000	-.729303	278.128	.0001	2.07914E-03

POLYNOMIAL APPROXIMATION FOR SILICON   STOPPING POWER S=C*E**ALPHA, RANGE R=CRL*E**(1-ALPHA).

PARTICLE T

LOWER E	UPPER E	ALPHA	C	MAX. DEV	CRL
ERROR= .1 0/0					
1.000	1.200	-.401724	302.610	-.1043	2.35751E-03
1.200	1.400	-.385125	301.695	.3223	2.39300E-03
1.400	1.800	-.510147	314.657	-.1099	2.10447E-03
1.800	2.300	-.545983	321.356	-.1061	2.01284E-03
2.300	3.000	-.582705	331.337	-.1226	1.90691E-03
3.000	3.900	-.617808	344.364	-.1053	1.79496E-03
3.900	5.200	-.650374	359.970	-.1126	1.68326E-03
5.200	7.200	-.680768	378.468	-.1130	1.57204E-03
7.200	10.200	-.706990	398.575	-.1052	1.46980E-03
10.200	15.500	-.729743	420.202	-.1105	1.37581E-03
15.500	24.500	-.750656	444.992	-.1019	1.28365E-03
24.500	40.500	-.768623	471.315	-.1013	1.19965E-03
40.500	168.000	-.781536	494.388	.1047	1.13537E-03
168.000	200.000	-.765477	455.335	.0202	1.24396E-03
ERROR= .3 0/0					
1.000	1.600	-.424745	302.610	-.4142	2.31942E-03
1.600	2.500	-.543431	319.970	-.3545	2.02490E-03
2.500	3.900	-.605842	338.802	-.3180	1.83803E-03
3.900	6.400	-.661029	365.228	-.3122	1.64838E-03
6.400	11.800	-.707354	398.025	-.3100	1.47152E-03
11.800	25.000	-.744697	436.453	-.3124	1.31324E-03
25.000	67.000	-.775320	481.667	-.3022	1.16944E-03
67.000	198.000	-.779207	489.604	.3078	1.14797E-03
198.000	200.000	-.760933	444.505	.0001	1.27756E-03
ERROR= .6 0/0					
1.000	1.700	-.434884	302.610	-1.5424	2.30303E-03
1.700	3.100	-.563387	323.964	-.6248	1.97441E-03
3.100	6.000	-.644674	355.171	-.6008	1.71192E-03
6.000	14.800	-.711824	400.581	-.6041	1.45831E-03
14.800	52.000	-.763084	459.916	-.6142	1.23324E-03
52.000	200.000	-.779926	491.562	.3468	1.14293E-03
ERROR= 1.0 0/0					
1.000	1.700	-.434884	302.610	-1.5424	2.30303E-03
1.700	3.700	-.575552	326.062	-1.0058	1.94656E-03
3.700	10.000	-.677757	372.712	-1.0314	1.59918E-03
10.000	41.000	-.750625	440.799	-1.0111	1.29588E-03
41.000	200.000	-.779807	491.253	.2941	1.14373E-03

PARTICLE HE 3

LOWER E	UPPER E	ALPHA	C	MAX. DEV	CRL
ERROR= .1 0/0					
1.000	1.100	-.239861	1183.209	-.4695	6.81656E-04
1.100	1.600	-.411304	1202.702	-.4314	5.89144E-04
1.600	2.100	-.530978	1272.290	-.1386	5.13387E-04
2.100	2.700	-.568649	1308.352	-.1169	4.87248E-04
2.700	3.500	-.604184	1355.355	-.1151	4.59931E-04
3.500	4.600	-.637166	1412.529	-.1083	4.32424E-04
4.600	6.200	-.668201	1481.037	-.1096	4.04749E-04
6.200	8.600	-.695216	1555.867	-.1027	3.79142E-04
8.600	12.600	-.719475	1639.238	-.1045	3.54783E-04
12.600	19.000	-.740286	1727.994	-.1030	3.32535E-04
19.000	30.500	-.758999	1825.876	-.1068	3.11360E-04
30.500	54.000	-.775868	1934.240	-.1009	2.91125E-04
54.000	150.000	-.783212	1991.737	.1023	2.81556E-04
150.000	200.000	-.767962	1845.220	.0475	3.06534E-04
ERROR= .3 0/0					
1.000	1.100	-.239861	1183.209	-.4695	6.81656E-04
1.100	1.600	-.411304	1202.702	-.4314	5.89144E-04
1.600	2.500	-.543460	1279.776	-.3544	5.06257E-04
2.500	3.900	-.605867	1355.090	-.3180	4.59539E-04
3.900	6.400	-.661048	1460.776	-.3122	4.12130E-04
6.400	11.800	-.707367	1591.933	-.3100	3.67916E-04
11.800	25.000	-.744705	1745.610	-.3124	3.28345E-04
25.000	67.000	-.775325	1926.423	-.3022	2.92395E-04
67.000	198.000	-.779203	1958.090	.3080	2.87040E-04
198.000	200.000	-.760922	1777.660	.0001	3.19456E-04
ERROR= .6 0/0					
1.000	1.200	-.308034	1183.209	-.6477	6.46129E-04
1.200	1.700	-.436239	1211.192	-.7652	5.74858E-04
1.700	3.100	-.563414	1295.747	-.6247	4.93635E-04
3.100	6.000	-.644696	1420.558	-.6007	4.28012E-04
6.000	14.800	-.711837	1602.156	-.6040	3.64614E-04
14.800	52.000	-.763090	1839.439	-.6141	3.08347E-04
52.000	200.000	-.779923	1965.937	.3470	2.85778E-04
ERROR= 1.0 0/0					
1.000	1.600	-.376537	1183.209	-1.0545	6.13975E-04
1.600	3.500	-.567343	1294.222	-1.0409	4.92977E-04
3.500	9.000	-.670556	1472.868	-1.0123	4.06420E-04
9.000	34.500	-.744729	1733.574	-1.0088	3.30620E-04
34.500	200.000	-.779261	1959.052	.2116	2.86889E-04

POLYNOMIAL APPROXIMATION FOR SILICON   STOPPING POWER S=C*E**ALPHA, RANGE R=CRL*E**(1-ALPHA).

PARTICLE HE 4

LOWER E	UPPER E	ALPHA	C	MAX. DEV	CRL
ERROR= .1 0/0					
1.000	1.100	-.114566	1224.494	.1434	7.32719E-04
1.100	1.300	-.120875	1225.231	-.1984	7.28157E-04
1.300	1.500	-.253018	1268.454	-.8041	6.29170E-04
1.500	2.100	-.411056	1352.396	-.3399	5.24025E-04
2.100	2.700	-.527499	1474.429	-.1162	4.44013E-04
2.700	3.500	-.564770	1530.034	-.1218	4.17684E-04
3.500	4.600	-.601978	1603.043	-.1191	3.89402E-04
4.600	6.000	-.635621	1687.494	-.1042	3.62306E-04
6.000	8.000	-.665928	1781.663	-.1034	3.36913E-04
8.000	11.200	-.693389	1886.365	-.1094	3.13053E-04
11.200	16.500	-.718495	2004.317	-.1114	2.90326E-04
16.500	25.000	-.739762	2127.448	-.1079	2.70179E-04
25.000	39.500	-.758369	2258.766	-.1003	2.51778E-04
39.500	70.000	-.775243	2403.318	-.1039	2.34386E-04
70.000	200.000	-.783152	2485.444	.0831	2.25636E-04
ERROR= .3 0/0					
1.000	1.400	-.124199	1224.494	-.3188	7.26440E-04
1.400	2.100	-.404076	1345.410	-.4023	5.29365E-04
2.100	3.200	-.539900	1488.057	-.3230	4.36403E-04
3.200	5.000	-.601226	1598.081	-.3213	3.90795E-04
5.000	8.200	-.657368	1749.203	-.3160	3.44938E-04
8.200	15.000	-.704679	1932.295	-.3112	3.03588E-04
15.000	31.500	-.742569	2141.094	-.3009	2.68024E-04
31.500	81.000	-.773503	2382.237	-.3049	2.36692E-04
81.000	200.000	-.783138	2485.265	.0949	2.25654E-04
ERROR= .6 0/0					
1.000	1.500	-.166029	1224.494	-1.1715	7.00380E-04
1.500	2.200	-.423023	1358.974	-.6384	5.17103E-04
2.200	4.000	-.559613	1513.501	-.6230	4.23644E-04
4.000	7.800	-.641878	1696.334	-.6111	3.59044E-04
7.800	18.500	-.709373	1948.602	-.6167	3.00220E-04
18.500	60.000	-.759650	2256.487	-.6133	2.51849E-04
60.000	200.000	-.782804	2480.863	.0507	2.26096E-04
ERROR= 1.0 0/0					
1.000	1.500	-.166029	1224.494	-1.1715	7.00380E-04
1.500	2.400	-.441665	1369.285	-1.2492	5.06573E-04
2.400	5.200	-.583613	1550.472	-1.0283	4.07274E-04
5.200	14.400	-.683771	1828.848	-1.0015	3.24743E-04
14.400	64.000	-.755333	2213.465	-1.0143	2.57376E-04
64.000	200.000	-.782977	2483.150	.0662	2.25866E-04

PARTICLE LI 7

LOWER E	UPPER E	ALPHA	C	MAX. DEV	CRL
ERROR= .1 0/0					
1.000	1.300	.145035	1870.058	.2437	6.25456E-04
1.300	1.500	.074484	1904.996	-.5706	5.67181E-04
1.500	1.800	-.080263	2028.353	-.1521	4.56381E-04
1.800	2.200	-.031872	1971.472	-.1294	4.91568E-04
2.200	3.000	-.252848	2346.702	-.1022	3.40129E-04
3.000	3.300	-.228107	2283.774	.1302	3.56542E-04
3.300	4.600	-.204832	2221.187	-.2075	3.73670E-04
4.600	5.800	-.281061	2495.205	-.1915	3.12841E-04
5.800	8.600	-.414103	3152.638	-.1099	2.24308E-04
8.600	9.000	-.469883	3554.679	-.1039	1.91389E-04
9.000	11.600	-.563372	4365.279	-.1058	1.46530E-04
11.600	13.600	-.594882	4715.771	-.1013	1.32959E-04
13.600	18.500	-.629789	5165.601	-.1208	1.18781E-04
18.500	23.500	-.677590	5938.721	-.1050	1.00374E-04
23.500	35.500	-.729072	6986.801	-.1060	8.27768E-05
35.500	56.000	-.749989	7528.431	-.1050	7.59032E-05
56.000	93.000	-.768101	8097.812	-.1041	6.98434E-05
93.000	198.000	-.782680	8651.001	-.1008	6.48426E-05
198.000	200.000	-.785738	8792.067	.0000	6.36929E-05
ERROR= .3 0/0					
1.000	1.400	.146502	1870.058	.3661	6.26531E-04
1.400	1.800	-.060549	2004.984	-.3732	4.70282E-04
1.800	2.300	-.069684	2015.779	-.6103	4.63769E-04
2.300	3.600	-.236902	2317.025	.4191	3.48926E-04
3.600	5.000	-.223643	2278.003	-.4188	3.58749E-04
5.000	6.000	-.311082	2622.235	-.4115	2.90870E-04
6.000	9.200	-.427981	3233.234	-.3816	2.16591E-04
9.200	13.800	-.578224	4512.724	-.3194	1.40408E-04
13.800	20.500	-.640425	5313.012	-.3345	1.14737E-04
20.500	31.500	-.712813	6611.436	-.3078	8.83068E-05
31.500	68.000	-.751107	7545.228	-.3074	7.56859E-05
68.000	200.000	-.779428	8502.974	-.2751	6.60920E-05
ERROR= .6 0/0					
1.000	1.600	.095632	1870.058	-1.2878	5.91289E-04
1.600	2.400	-.097473	2047.726	-.8778	4.44974E-04
2.400	3.800	-.227901	2295.419	.6201	3.54793E-04
3.800	5.800	-.251531	2368.983	-.6550	3.37285E-04
5.800	9.600	-.436925	3281.689	-.7299	2.12065E-04
9.600	16.500	-.594031	4681.858	-.6058	1.33994E-04
16.500	27.000	-.682865	6005.814	-.6194	9.89416E-05
27.000	79.000	-.750540	7506.541	-.6032	7.61006E-05
79.000	200.000	-.781131	8580.057	-.1810	6.54356E-05
ERROR= 1.0 0/0					
1.000	1.600	.095632	1870.058	-1.2878	5.91289E-04
1.600	2.500	-.110012	2059.829	-1.3363	4.37362E-04
2.500	6.200	-.251569	2345.106	-1.0130	3.40708E-04
6.200	10.200	-.455958	3405.012	-1.1403	2.01712E-04
10.200	21.500	-.620342	4987.882	-1.0419	1.23731E-04
21.500	78.000	-.743112	7269.417	-1.0152	7.89178E-05
78.000	200.000	-.780998	8573.997	-.1880	6.54867E-05

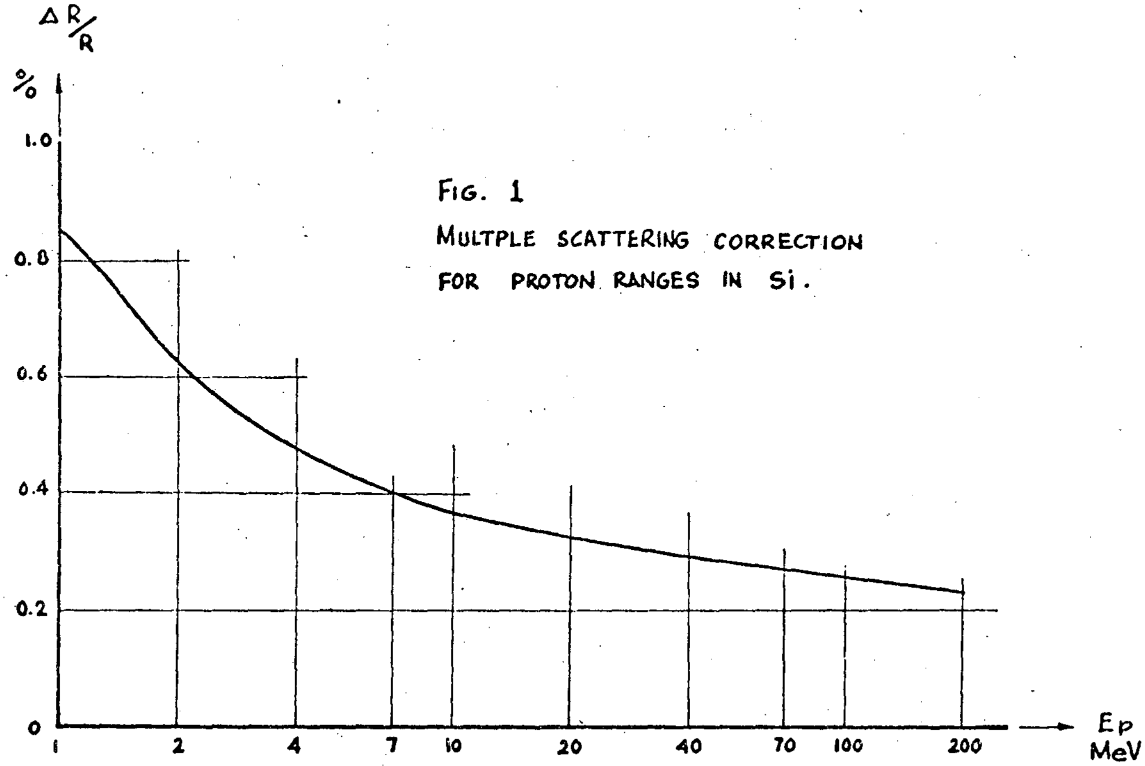


FIG. 1
MULTPLE SCATTERING CORRECTION FOR PROTON RANGES IN Si.

XBL 677-4253

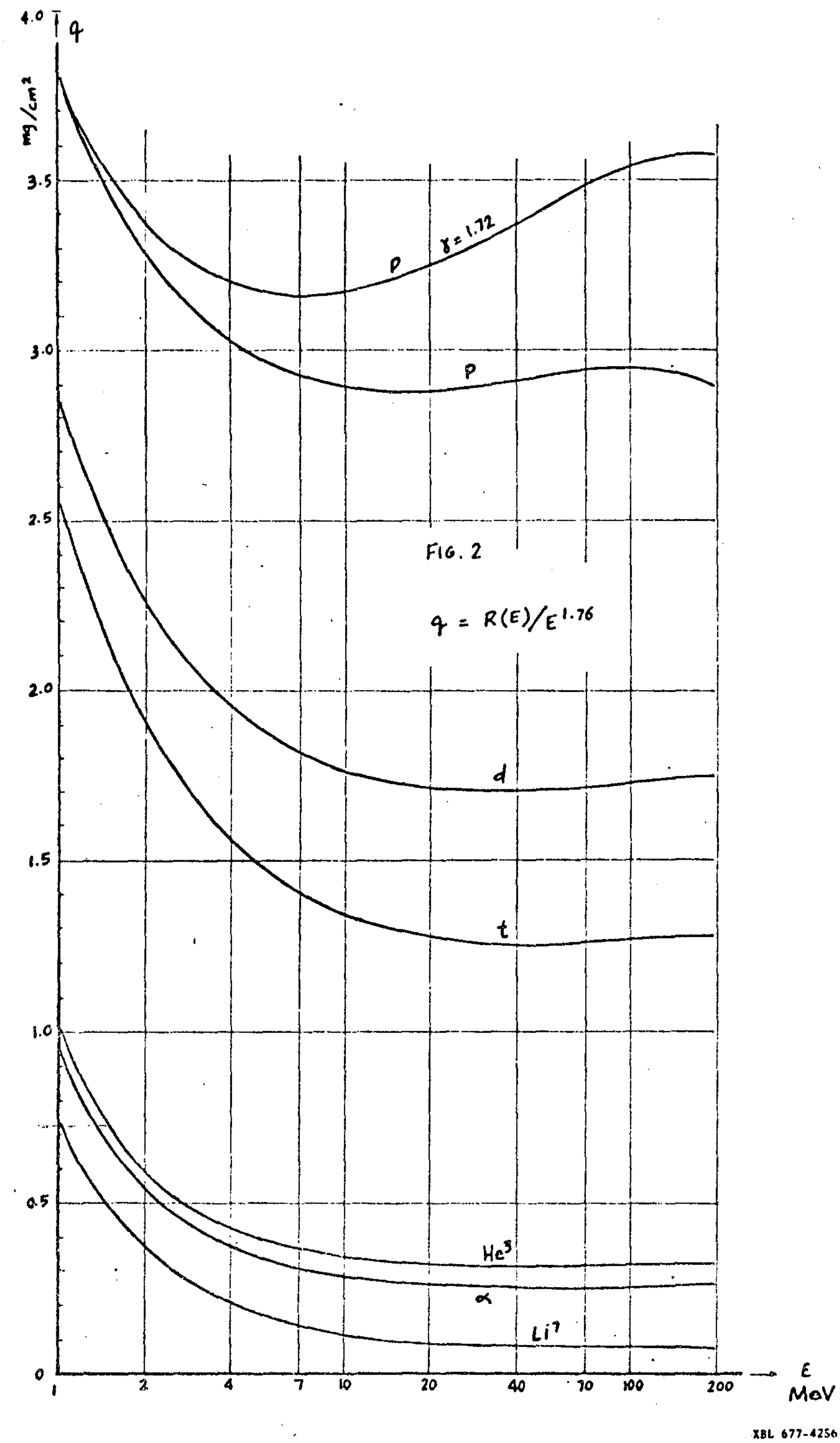

4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
q
mg/cm²
p
γ=1.72
p
FIG. 2
q = R(E)/E^1.76
d
t
He³
α
Li⁷
1
2
4
7
10
20
40
70
100
200
E
MeV
XBL 677-4256

Fig. 2

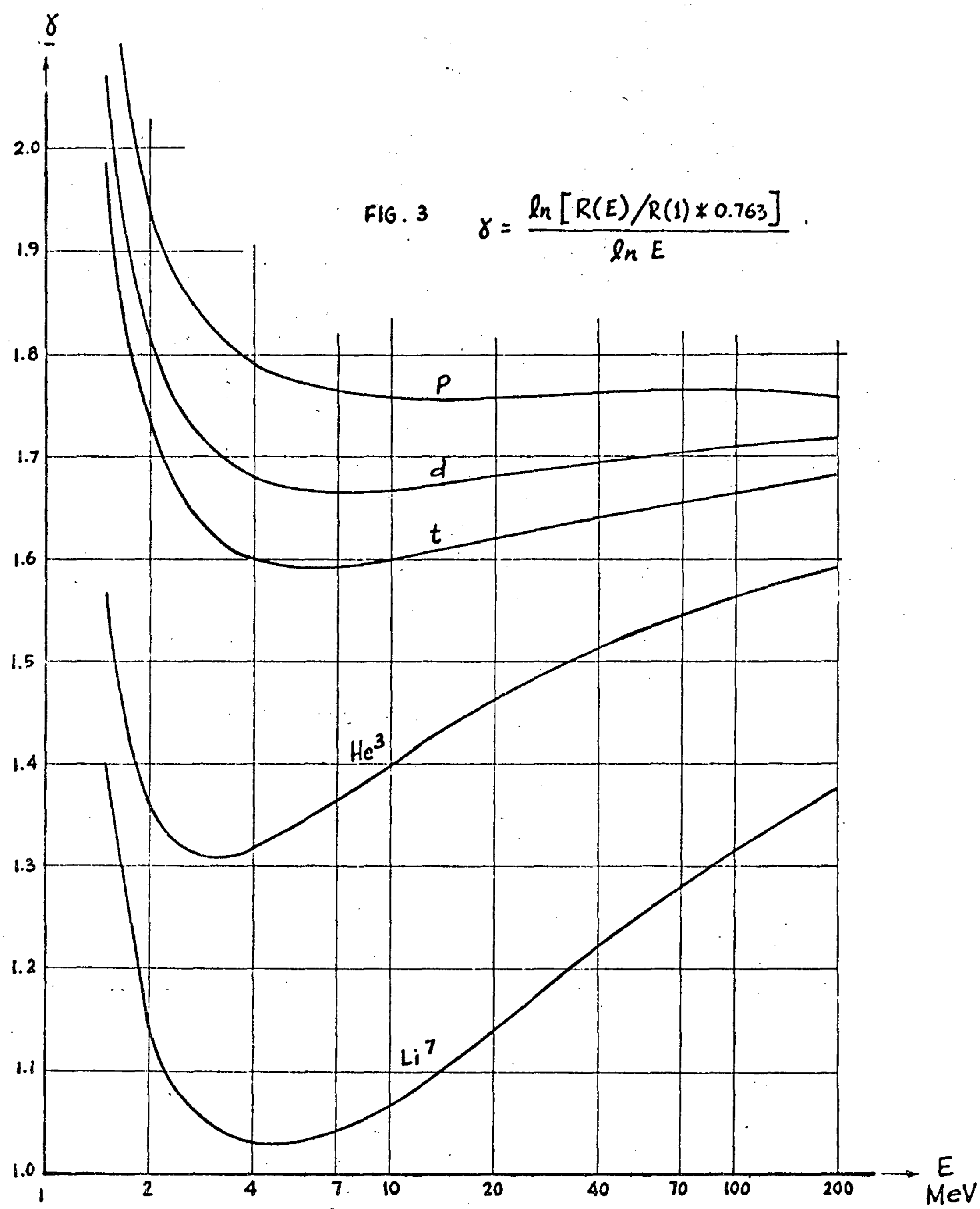
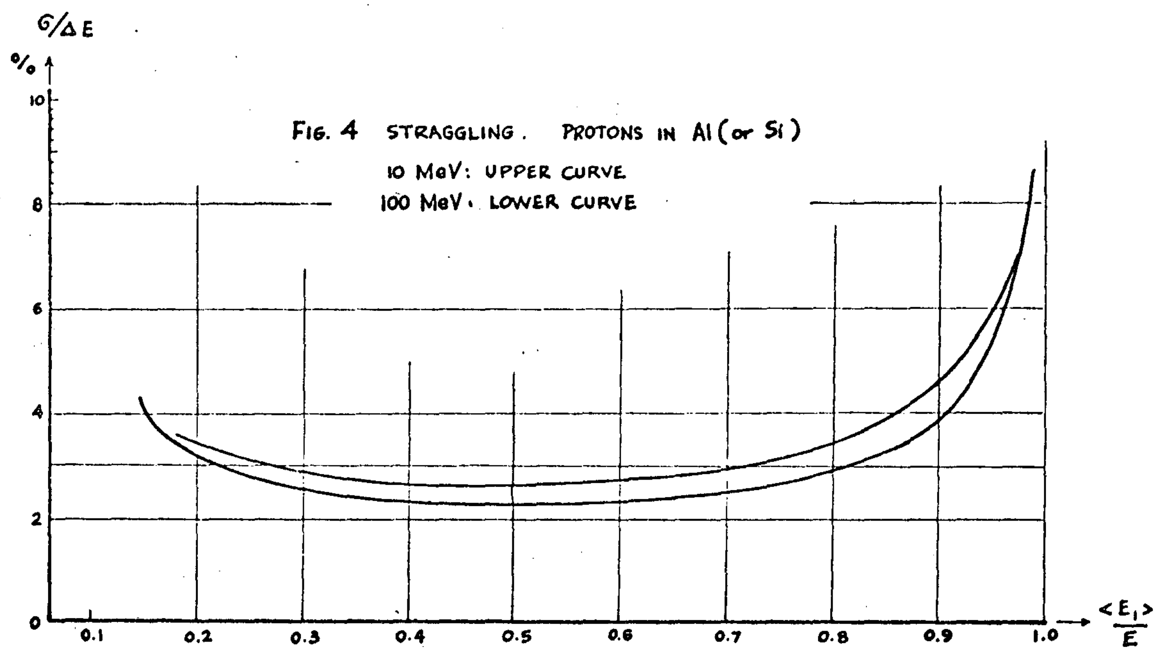


FIG. 3
$\gamma = \frac{\ln[R(E)/R(1) * 0.763]}{\ln E}$
γ
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
P
d
t
He^3
Li^7
1
2
4
7
10
20
40
70
100
200
E
MeV

XBL 677-4257


σ/ΔE
%
10
8
6
4
2
0
FIG. 4 STRAGGLING. PROTONS IN Al (or Si)
10 MeV: UPPER CURVE
100 MeV: LOWER CURVE
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
<E1>/E

XBL 677-4254

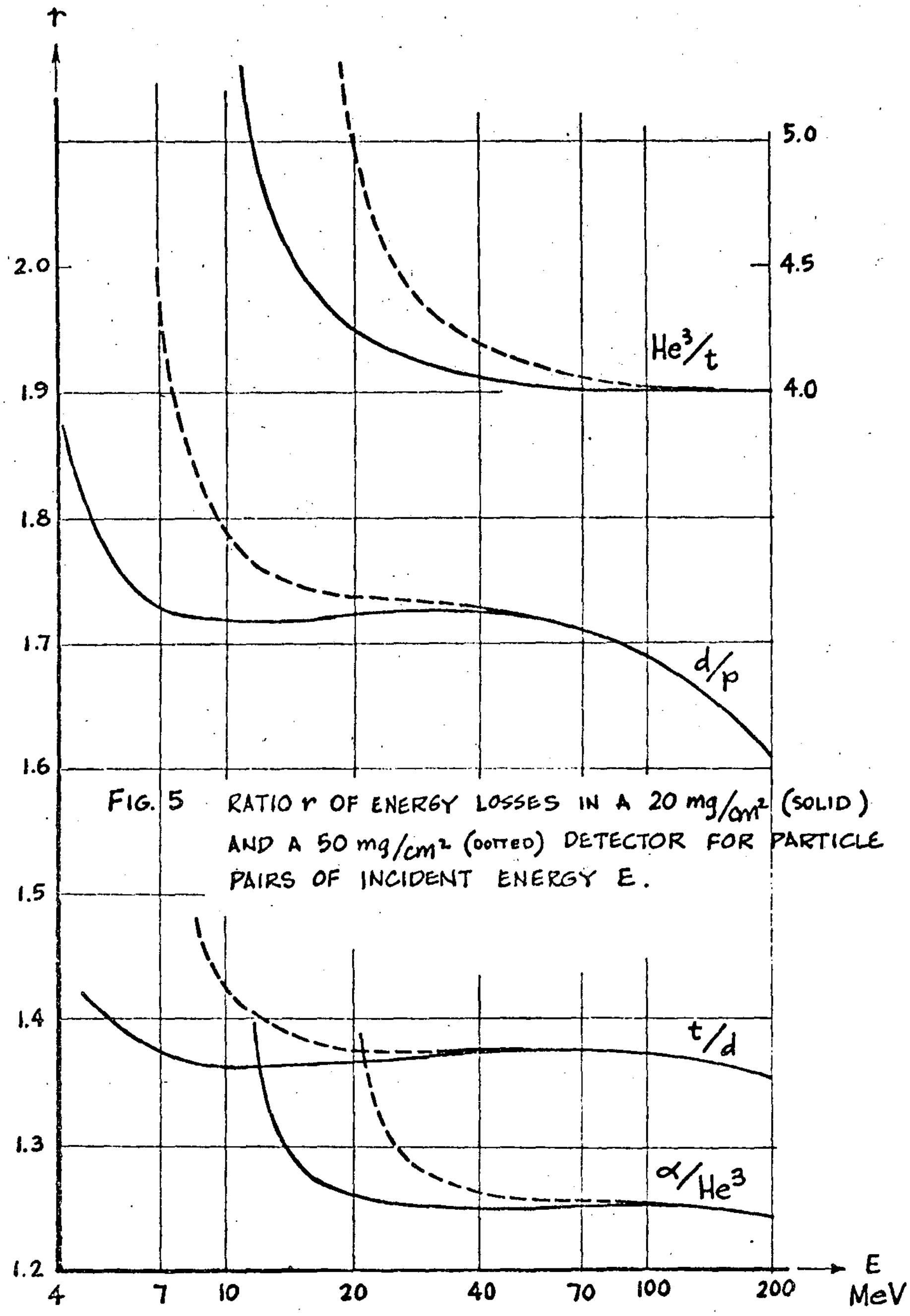
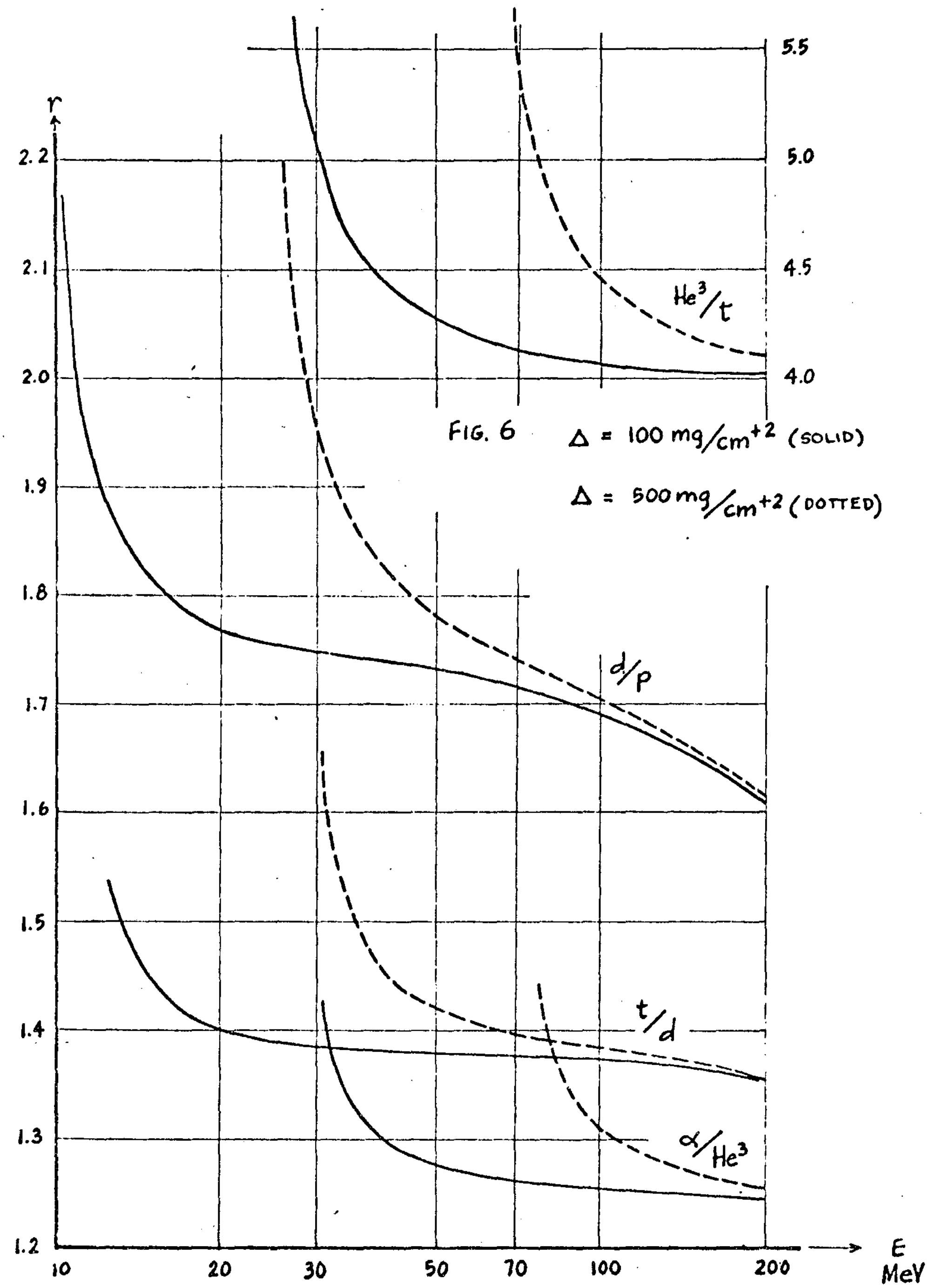
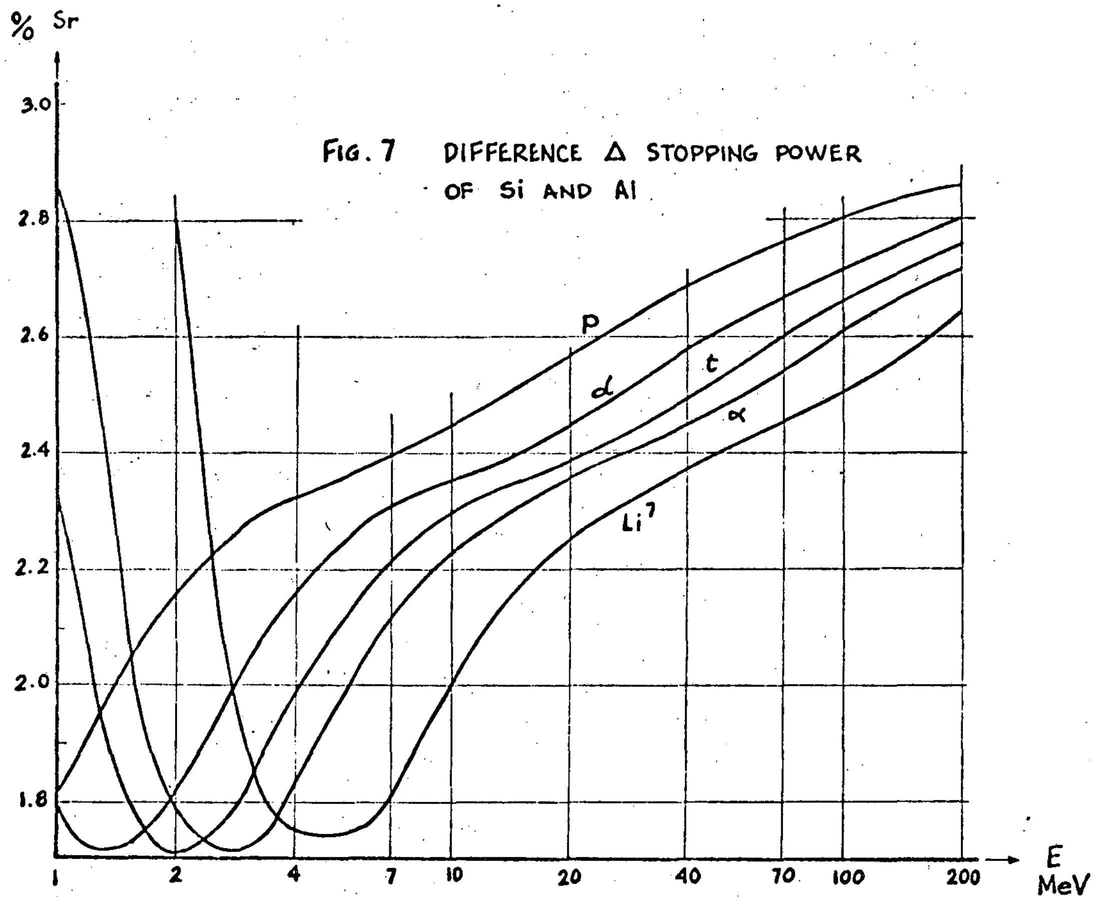


FIG. 5 RATIO r OF ENERGY LOSSES IN A 20 mg/cm² (SOLID) AND A 50 mg/cm² (DOTTED) DETECTOR FOR PARTICLE PAIRS OF INCIDENT ENERGY E.

XBL 677-4258


r
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
5.5
5.0
4.5
4.0
10
20
30
50
70
100
200
E
MeV
He³/t
d/p
t/d
α/He³
FIG. 6
Δ = 100 mg/cm+2 (SOLID)
Δ = 500 mg/cm+2 (DOTTED)

XBL 677-4259


% Sr
3.0
2.8
2.6
2.4
2.2
2.0
1.8
FIG. 7 DIFFERENCE Δ STOPPING POWER OF Si AND Al
p
d
t
α
Li7
1
2
4
7
10
20
40
70
100
200
E MeV

XBL 677-4255