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ANL-PHY-79-1
May 1979

ARGONNE NATIONAL LABORATORY*
9700 South Cass Avenue
Argonne, Illinois 60439

COMPUTER SIMULATION OF ION ORBITS IN THE
ARGONNE SUPERCONDUCTING HEAVY-ION LINAC

(TEST VERSION)

by

Murray Peshkin

Physics Division

*Work performed under the auspices of the U. S. Dept. of Energy.

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ABSTRACT

The bunch profile is computed in one space dimension, as a function of the available parameters. Transverse motion is neglected.

I. SUMMARY

This report presents a quick-and-dirty treatment of the orbits of heavy ions in the Argonne superconducting heavy-ion linac. My purpose was, with minimal effort, to provide a computer simulation of the linac. The operator should be able to calculate the effects of varying the controls (field amplitudes and phases) upon the profile of a bunch of ions emerging from the linac; and he should be able to do that quickly and cheaply.

I have dealt with only the one-dimensional problem. Motion of the ions in the directions transverse to the axis of the resonator was ignored. The procedure was the following:

1. The one-dimensional equation of motion for a single ion traversing a single resonator was solved numerically in 1800 cases. The energy gain and passage time through the resonator were tabulated as functions of three variables which summarize the initial condition of the ion and the field settings of the resonator.
2. A computer program was written to calculate and display the profile of a bunch of ions leaving the resonator, starting from the field settings and the profile of the incident bunch, by interpolating among the 1800 tabulated cases.

The Simulator consists of the tables and the interpolation-display program. It is currently run under Speakeasy on the Argonne IBM 360/75 time-sharing computer, from any typewriter-like terminal. The profile of the emergent beam appears as a crude graph. The operator can easily link successive resonators by typing very few Speakeasy statements. The real time needed to simulate a bunch going through one resonator is somewhat less than two minutes. The cost is about ten cents off prime time, or forty cents during prime time. Continued dependence upon the IBM 360 may prove to be a significant nuisance. Now that the tables have been calculated, it would be feasible to transfer the Simulator to a mini-computer, and that probably should be done if experience shows the Simulator to be useful.

The major disadvantage of the present Simulator is that it cannot be generalized to include transverse motion of the ions if that should prove necessary. To solve the three-dimensional equations of motion would be no

more difficult than to solve the one-dimensional equation. However, to tabulate the results for an adequate number of cases would probably expand both the computational effort and the size of the tables past the point where a new approach to the problem would be needed.

The details of the procedure to solve the differential equations, the tests performed upon those solutions, and the tests performed upon the accuracy of the interpolation scheme are omitted from this report. Briefly, the one-dimensional equation of motion (2.1) was converted to two coupled first-order nonlinear differential equations. A Speakeasy program was written to solve many cases at a time by invoking the standard Episode package for simultaneous first-order nonlinear differential equations. The resulting solutions were tested in sample cases against the differential equations themselves. The accuracy of the interpolation was confirmed in the most sensitive regimes by comparison with direct solutions. In all the tabulated cases, the accuracy of the results appears to be orders of magnitude better than necessary. However, the errors that may have been introduced by neglecting the transverse motion of the ions are unknown.

Section II below is a manual for using the Simulator, with examples. Section III contains all the tables on which the interpolater acts, along with precise definitions of the tabulated quantities. The tables may be useful for obtaining information without resort to the interpolation-display program. Section IV presents the interpolation-display program with explanatory notes. That material may be useful for modifying the program but, like the tables, it is superfluous for using the Simulator.

II. THE SIMULATOR ... HOW TO USE IT

The Simulator consists of a computer program called BOX4 and a set of tables which summarize the information that was obtained by solving the equations of motion. The computer program operates under time-sharing Speakeasy. Its function is to interpolate in the tables to obtain the profile (in the energy-phase plane) of a bunch of ions which have traversed a resonator, and to display that profile on a typewriter-like terminal.

Operating Instructions

Access

1. Under TSO, invoke FEDEASY instead of SPEAKEZ. (Fedeasy is an enhancement of Speakeasy which is used because it has better graphical output on a typewriter terminal.)
2. SIZE 120. This can be varied to optimize the trade off between space for data and space for loaded linkules.
3. RESTORE BOXES. (The checkpointed file BOXES contains program BOX4, the tables on which it operates, and some stored instructions to the program which do not concern the user.)
4. LOAD GRAPHZ, INTERPLAG, MAX, INTEGERS, NOELS, TRANSPOSE. (The purpose of this step is to accelerate the execution of program BOX4 by loading the Speakeasy linkules which it most needs^{*}.)

Input information

An entering bunch of ions is thought of as consisting of a reference particle and a number (perhaps 100) of profile particles that somehow represent the edge of the bunch in the energy-phase plane. The reference particle is characterized by its energy EIN and the phase of the resonator THETAREF, relative to the phase which would produce maximum acceleration for fixed values of all other variables. The phase convention is defined more precisely by Eqs. (3.1) and (3.6). To use the Simulator it is sufficient to know that, within the range of the tables, positive THETAREF is the bunching region and

* In a test run off prime time, a single execution of BOX4 cost 17¢ with nothing loaded, 12¢ with only GRAPHZ and INTERPLAG loaded, and 10¢ with all the listed linkules loaded.

negative THETAREF is the debunching region.

The profile particles are described by giving their energies DELEIN relative to the energy of the reference particle, and their phases DELPHIIN relative to the reference particle. Positive DELPHIIN represents a particle which arrives at the entrance to the resonator earlier than the reference particle, the time difference being expressed as the phase difference of the electric field, in degrees. Thus,

$$\text{DELPHIIN} = 360 \cdot (\text{frequency}) \cdot \delta t.$$

The operator must provide the following data:

1. Q and A. Charge number and mass number of the ions.
2. EAX The amplitude of the axial electric field in MV/m.
 Eqs. (3.1) and (3.2) give a precise definition.
 Restriction: $.25 \leq Q \cdot \text{EAX} / A \leq 2.5$
3. EIN Reference particle energy in MeV.
 Restriction: $1.6767 \leq \text{EIN} / A \leq 10.479$
4. THETAREF Phase of the resonator in degrees, as explained above.
 Restriction: $-50 \leq \text{THETAREF} \leq 140$
5. DELEIN Two arrays of equal length (perhaps 100) representing
 DELPHIIN the relative energies and phases of the profile particles,
 as explained above.
6. GAP The distance in meters from the exit of the resonator to
 the point where the profile of the emergent bunch is
 wanted. Ordinarily, GAP would be the distance to the
 entrance of the next resonator or to a target.
 Restriction: $\text{GAP} \geq 0.$

Output information

The program prints out the input information, except for the arrays DELEIN and DELPHIIN, and it prints out the emergent energy EOUT of the reference particle. It presents the profile of the emerging batch, at the point specified by GAP, in the form of a graph of DELEOUT vs. DELPHOUT. Those two arrays remain in the memory for use in the next calculation, as does the passage time through the resonator (see Section III).

In addition, the program calculates and prints an angle called SETBACK, in degrees. The point of this is that the operator is not expected to know the absolute phase of the resonator. He could adjust the phase to the point of maximum acceleration ϕ_{max} and then advance it by the desired

amount THETAREF. However maxima are hard to locate; it is easier to find the reference angle θ_0 for zero acceleration (on the positive bunching side of the maximum) and then back off by the amount

$$\text{SETBACK} = \theta_0 - \text{THETAREF} \quad (2.1)$$

The program finds θ_0 by interpolation in Table (3.4) and then uses Eq. (2.1) to determine SETBACK.

Successive resonators

For the first resonator, all the input information must be supplied by the operator. For successive resonators, the same values are automatically used unless they are changed by the operator. The operator may want to save the output quantities under a new name, so that they will not be redefined when the program is rerun. For instance, the command sequence

```

E3 = EOUT
DE3 = DELEOUT
DP3 = DELPHOUT
GAP = .42
EIN = EOUT
DELEIN = DELEOUT
DELPHIIN = DELPHOUT
BOX4

```

saves the results from resonator number 3, changes the GAP but leaves Q, A, EAX, and THETAREF unchanged, uses the emerging profile from resonator 3 as the entering profile for resonator 4, and runs the Simulator. Of course one could also change only EAX and/or THETAREF, and run resonator 3 again. In that case the entering profile would not have to be changed.

Caveat

If input values outside of the range covered by the tables are used, the program will automatically extrapolate and possibly produce nonsensical results. The danger is especially great if EIN is too low. A warning message appears if (EIN/A) or $(Q \cdot \text{EAX}/A)$ lies outside the tabulated bounds. GAP and THETAREF are not protected by warning messages.

Examples

The following examples illustrate the operation of the Simulator and present a few simple manipulations of the results. The initial profile values DELPHIIN and DELEIN have been chosen to be relatively large, to emphasize the distortion of the initial phase ellipse by the resonator. Input lines can be recognized by the lower-case letters.

```

:_load graphz,interplag,max,integers,noels,transpose
:_alpha=variable(0,360,4)
:_delein=cos(alpha)
:_delphiin=10*sin(alpha)
:_graphz(delein:delphiin)
SYMBOL: * IS DELEIN

```

```

:_areaain=totalint(delein:delphiin)
:_areaain
AREAIN = 31.39
:_

```

```

:_q=15;a=30;eax=4.2;thetaref=40;gap=.1;ein=65
:_box4
EXECUTION STARTED
EIN = 65   THETAREF = 40   GAP = .1
SETBACK = 84.563   EOUT = 75.347
SYMBOL: * IS DELEOUT

```

MANUAL MODE

```
:_areal=totalint(deleout:delphout)
```

```
:_areal
```

```
AREA1 = 31.396
```

```
:_ycenter=.5*totalint(deleout**2:delphout)/totalint(deleout:delphout)
```

```
:_xcenter=.5*totalint(delphout**2:deleout)/totalint(delphout:deleout)
```

```
:_xcenter,ycenter
```

```
XCENTER = -.081197   YCENTER = -.023667
```

```
:_
```

```
:_thetaref=20
```

```
:_box4
```

```
EXECUTION STARTED
```

```
EIN = 65 THETAREF = 20 GAP = .1
```

```
SETBACK = 104.56 EOUT = 76.925
```

```
SYMBOL: * IS DELEOUT
```

```
MANUAL MODE
```

```
:_
```

```

:_el=eout;delel=deleout;delph1=delphout
:_ein=eout;delein=deleout;delphiin=delphout
:_money
NON-PRIME TIME
$ 0.48 - 1646 TOTAL EXCPS
$ 0.29 - 27.25 CPU SECS.
$ 0.20 - 0.5473 SESSION HOURS
$ 0.97 - ** TOTAL **
:_box4
EXECUTION STARTED
EIN = 76.925 THETAREF = 20 GAP = .1
SETBACK = 96.592 EOUT = 93.831
SYMBOL: * IS DELEOUT

```

MANUAL MODE

```

:_money
NON-PRIME TIME
$ 0.51 - 1764 TOTAL EXCPS
$ 0.35 - 32.33 CPU SECS.
$ 0.21 - 0.5943 SESSION HOURS.
$ 1.07 - ** TOTAL **
:_area2=totalint(deleout:delphout); area2
AREA2 = 31.37
:_

```

III. THE TABLES

The one-dimensional motion of an ion moving along the z axis of a resonator obeys

$$\left. \begin{aligned} \frac{d}{dt} \frac{\beta}{(1-\beta^2)^{1/2}} &= \frac{Qe E_{ax}}{AMc} F(z) \cos(2\pi ft - \phi_{res}) \\ \beta(t) &= \frac{1}{c} \frac{dz}{dt} \\ z(0) &= -L \\ \beta(0) &= \beta_{in} \end{aligned} \right\} \quad (3.1)$$

where the electric field shape $F(z)$ was taken as

$$F(z) = \sum_{n=1}^{10} F_c(n) \cos \frac{\pi n z}{L} . \quad (3.2)$$

Notation:

L	Half-length of a resonator (.203m).	$-L \leq z \leq L$.
Q, A	Ion charge number and mass number.	
E_{ax}	Amplitude of the axial electric field (MV/m).	
M	Nucleon mass ($931.5 \text{ MeV}/c^2$) .	
f	Resonator frequency ($98 \times 10^6 \text{ sec}^{-1}$) .	
ϕ_{res}	Resonator phase.	
t_{out}	Passage time through the resonator (sec). $z(t_{out}) = L$.	

The numerical values of the Fourier coefficients $F_c(n)$ (Table 3.1) were taken to be those used in calculations by other persons. A graph of $F(z)$ appears in Fig. (3.1).

Eqs. (3.1) have been solved numerically in many cases to obtain β_{out} as a function of the three input parameters β_{in} , ϕ_{res} , and

$$E_{eff} = Q E_{ax}/A . \quad (3.3)$$

Table (3.1). The Fourier coefficients $F_c(n)$

$\underline{n}$	$\underline{F_c(n)}$	$\underline{n}$	$\underline{F_c(n)}$
1	1.809	6	.034162
2	.62267	7	-.089603
3	.0074042	8	-.11284
4	.74068	9	-.020038
5	-.42789	10	.0070209

Fig. (3.1). The field shape $F(z)$ in a resonator.

Interpolations were then performed to find the critical phase angles,

$$\phi_{\max}(E_{\text{eff}}, \beta_{\text{in}}) = \text{value of } \phi_{\text{res}} \text{ for which } \beta_{\text{out}} \text{ is maximum,}$$

and

$$\phi_0(E_{\text{eff}}, \beta_{\text{in}}) = \text{the first value of } \phi_{\text{res}} \text{ for which } \beta_{\text{out}} = \beta_{\text{in}}.$$

Here the "first value" means that the angle

$$\theta_0 = (\phi_0 - \phi_{\max})(\text{mod. } 360^\circ) \quad (3.4)$$

is around 90° , not 270° .

Finally, the equations of motion were solved to obtain t_{out} and

$$\delta\beta = \beta_{\text{out}} - \beta_{\text{in}} \quad (3.5)$$

as functions of E_{eff} , β_{in} , and

$$\theta = \phi_{\text{res}} - \phi_{\max}(E_{\text{eff}}, \beta_{\text{in}}) \quad (3.6)$$

The results were tabulated for 1800 cases in the range

$$\begin{aligned} .06 &\leq \beta \leq .15 \\ .25 &\leq E_{\text{eff}} \leq 2.5 \text{ MV/m} \\ -50 &\leq \theta \leq 140^\circ, \end{aligned} \quad (3.7)$$

as follows:

Table 3.2 $\phi_{\max}$ as a function of E_{eff} and β_{in} .

Table 3.3 $\delta_{\max} = \delta\beta(\phi_{\max})$ as a function of E_{eff} and β_{in} .

Table 3.4 θ_0 as a function of E_{eff} and β_{in} .

Table 3.5 $\delta\beta$ as a function of E_{eff} , β_{in} , and θ .

Table 3.6 t_{out} as a function of E_{eff} , β_{in} , and θ .

The restriction to values of $\beta_{\text{in}} \geq .06$ was necessitated by a kind of antiresonance around $\beta_{\text{in}} = .059$ which is most efficiently seen by reference to the graphs of Fig. (3.2). For all $\beta_{\text{in}} > .06$, the behavior of $\phi_{\max}$ as a function of β_{in} is smooth. However in the antiresonance region, $\phi_{\max}$ undergoes sudden changes. Reliable interpolations in that regime would require the tables to be constructed on a finer grid.

Fig. (3.2). $\delta\beta$ vs ϕ for several values of β_{in} , with $(Q E_{ax}/A) = 2.25$

Table 3.2

$\phi_{\max}$ as a function
of β_{in} and E_{eff} .

BIN	E=.25	E=.75	E=1.25	E=1.5	E=2.0	E=2.5
.06	392.36	380.44	369.32	364.48	356.34	349.8
.061	387.18	377.94	368.6	364.18	356.24	349.51
.062	381.54	373.7	365.68	361.76	354.43	347.96
.063	375.83	368.9	361.8	358.3	351.62	345.55
.064	370.2	363.89	357.49	354.32	348.23	342.59
.065	364.67	358.85	352.99	350.09	344.49	339.26
.07	339.07	334.72	330.47	328.38	324.37	320.55
.08	297.89	294.15	291.3	289.92	287.25	284.69
.09	264.33	262.18	260.11	259.1	257.13	255.23
.1	238.08	236.48	234.93	234.17	232.69	231.25
.11	216.56	215.36	214.18	213.61	212.49	211.39
.12	198.61	197.69	196.8	196.36	195.5	194.65
.13	183.4	182.7	182.01	181.67	181	180.34
.14	170.36	169.81	169.27	169	168.48	167.96
.15	159.04	158.61	158.19	157.98	157.56	157.15

Table 3.3

$\delta_{\max}$ as a function
of β_{in} and E_{eff} .

BIN	E=.25	E=.75	E=1.25	E=1.5	E=2.0	E=2.5
.06	1.1818E-4	3.9022E-4	7.3921E-4	9.5552E-4	.0014985	.0222225
.061	1.8534E-4	6.0358E-4	.0011119	.0014119	.0021295	.0030362
.062	2.5286E-4	8.1556E-4	.0014231	.0018667	.0027567	.0039324
.063	3.1757E-4	.0012229	.0018447	.0023098	.0032629	.0046075
.064	3.8133E-4	.0012234	.002192	.0027319	.0039336	.0053314
.065	4.429E-4	.0014155	.002522	.0031321	.0044781	.0060035
.07	7.0848E-4	.0022233	.0032717	.0047462	.0065936	.0095658
.08	.0010138	.0030906	.0052227	.0063055	.0084969	.010712
.09	.0010939	.0032813	.0054513	.0065463	.0087825	.010836
.1	.001054	.0031378	.0051874	.0061988	.0081939	.010151
.11	9.6191E-4	.0028557	.0047097	.005622	.0074175	.009175
.12	8.538E-4	.0025336	.0041775	.0049262	.0065782	.0081369
.13	7.4707E-4	.0022184	.0036602	.0043703	.0057699	.0071425
.14	6.4921E-4	.0019299	.0031875	.003808	.0050326	.0062363
.15	5.6274E-4	.0016747	.0027693	.0033101	.0043795	.0054329

Table 3.4

θ_o as a function
of β_{in} and E_{eff} .

BIN	E=.25	E=.75	E=1.25	E=1.5	E=2.0	E=2.5
.06	97.687	113.21	127.68	134.1	145.2	154.45
.061	96.375	109.31	122.16	123.24	139.32	148.96
.062	95.705	107.32	118.94	124.6	135.22	144.76
.063	95.296	106.03	116.81	122.09	132.18	141.48
.064	94.986	105.09	115.21	120.18	129.79	138.77
.065	94.74	104.32	113.91	118.64	127.21	136.48
.07	93.804	101.46	109.12	112.94	120.46	127.82
.08	92.426	97.252	102.13	104.57	109.45	114.33
.09	91.503	94.475	97.417	98.879	101.8	104.71
.1	90.917	92.743	94.524	95.397	97.124	98.821
.11	90.574	91.696	92.802	93.329	94.376	95.393
.12	90.364	91.074	91.761	92.095	92.743	93.375
.13	90.234	90.691	91.13	91.34	91.76	92.165
.14	90.153	90.45	90.738	90.877	91.148	91.489
.15	90.102	90.297	90.479	90.578	90.759	90.938

Table 3.5

$\delta\beta$ as a function
of β_{in} , θ , and E_{eff} .

BIN	TH	E=0.25	E=0.75	E=1.25	E=1.5	E=2.0	E=2.5
.06	-50	7.3776E-5	2.1932E-4	3.5177E-4	4.1412E-4	5.4556E-4	7.066E-4
.06	-40	8.9427E-5	2.8165E-4	4.91E-4	6.0713E-4	8.7931E-4	.0012322
.06	-30	1.0193E-4	3.2966E-4	6.0179E-4	7.6207E-4	.0011526	.0016663
.06	-20	1.1097E-4	3.6397E-4	6.8204E-4	8.7203E-4	.0013435	.0017803
.06	-10	1.1639E-4	3.8392E-4	7.2509E-4	9.3559E-4	.0014625	.0021642
.06	0	1.1818E-4	3.9022E-4	7.321E-4	9.5553E-4	.0014985	.0022225
.06	10	1.1645E-4	3.8447E-4	7.2676E-4	9.3909E-4	.0014669	.0021708
.06	20	1.1144E-4	3.6849E-4	6.9332E-4	8.9151E-4	.0013927	.0020323
.06	30	1.0344E-4	3.4424E-4	6.4484E-4	8.2477E-4	.0012627	.0018339
.06	40	9.2797E-5	3.1355E-4	5.8681E-4	7.464E-4	.001124	.0016033
.06	50	7.9901E-5	2.7795E-4	5.2373E-4	6.635E-4	9.8156E-4	.0010674
.06	60	6.5152E-5	2.3873E-4	4.5865E-4	5.8106E-4	8.4712E-4	.0011481
.06	70	4.8959E-5	1.9687E-4	3.9318E-4	5.0168E-4	7.2764E-4	9.6132E-4
.06	80	3.1734E-5	1.5293E-4	3.2762E-4	4.2554E-4	6.2492E-4	8.1423E-4
.06	90	1.3887E-5	1.0756E-4	2.6143E-4	3.5111E-4	5.3577E-4	7.048E-4
.06	100	-4.1759E-6	6.1318E-5	1.9382E-4	2.7606E-4	4.5339E-4	6.2224E-4
.06	110	-2.2049E-5	1.4844E-5	1.2462E-4	1.9837E-4	3.695E-4	5.4959E-4
.06	120	-3.9333E-5	-3.1175E-5	5.4132E-5	1.1732E-4	2.7714E-4	4.6819E-4
.06	130	-5.5627E-5	-7.6042E-5	-1.6225E-5	3.4089E-5	1.7321E-4	3.6322E-4
.06	140	-7.0536E-5	-1.1913E-4	-8.4534E-5	-4.8451E-5	6.0084E-5	2.2924E-4
.061	-50	1.1726E-4	3.6251E-4	6.1234E-4	7.3797E-4	.0010005	.0012988
.061	-40	1.4115E-4	4.493E-4	7.9266E-4	9.8229E-4	.001407	.0015201
.061	-30	1.603E-4	5.1767E-4	9.3612E-4	.0011748	.0017301	.0024176
.061	-20	1.742E-4	5.6613E-4	.0010351	.0013099	.0019577	.0027696
.061	-10	1.8257E-4	5.9447E-4	.0010937	.0013875	.0020385	.0029724
.061	0	1.8535E-4	6.0357E-4	.0011119	.0014119	.0021295	.0030362
.061	10	1.8266E-4	5.9509E-4	.0010956	.0013903	.0020935	.0029301
.061	20	1.7478E-4	5.7114E-4	.001051	.0013318	.0019967	.0028296
.061	30	1.6213E-4	5.3406E-4	9.8449E-4	.0012457	.0018558	.0026123
.061	40	1.4521E-4	4.8612E-4	9.0192E-4	.0011409	.0016907	.0023562
.061	50	1.2462E-4	4.2942E-4	8.0822E-4	.0010246	.001513	.0020966
.061	60	1.0097E-4	3.655E-4	7.0702E-4	9.0216E-4	.0013346	.0019241
.061	70	7.4944E-5	2.9687E-4	6.0064E-4	7.7659E-4	.0011622	.0015826
.061	80	4.7223E-5	2.2402E-4	4.6039E-4	6.4898E-4	9.9761E-4	.001368
.061	90	2.9522E-5	1.4053E-4	2.7699E-4	5.1914E-4	8.7653E-4	.0011777
.061	100	-1.0507E-5	7.1687E-5	2.6082E-4	3.8642E-4	6.8317E-4	.0010025
.061	110	-3.9115E-5	-5.2444E-6	1.4305E-4	2.5269E-4	5.1727E-4	8.2859E-4
.061	120	-6.6622E-5	-8.097E-5	2.5222E-5	1.1304E-4	3.4649E-4	6.4265E-4
.061	130	-9.2345E-5	-1.5423E-4	-9.0495E-5	-2.3975E-5	1.6834E-4	4.3634E-4
.061	140	-1.1561E-4	-2.2383E-4	-2.0178E-4	-1.5682E-4	-1.2118E-5	2.1032E-4
.062	-50	1.6049E-4	5.0297E-4	8.6629E-4	.0010578	.0014574	.0019807
.062	-40	1.9256E-4	6.1526E-4	.0010917	.0013524	.0019303	.0025054
.062	-30	2.1829E-4	7.0353E-4	.0012556	.001583	.002302	.0031597
.062	-20	2.3701E-4	7.665E-4	.0013335	.0017444	.0025614	.0035472
.062	-10	2.483E-4	8.0355E-4	.0014605	.0019373	.00271	.003769
.062	0	2.5206E-4	8.1556E-4	.0014831	.0019667	.0027566	.0038384
.062	10	2.4839E-4	8.043E-4	.0014626	.0018404	.0027154	.0037772
.062	20	2.3764E-4	7.722E-4	.0014056	.0017681	.0026035	.0035119
.062	30	2.2034E-4	7.2136E-4	.001319	.0016597	.002439	.0033707
.062	40	1.9715E-4	6.5632E-4	.0012295	.0015246	.002239	.0030813
.062	50	1.6887E-4	5.7816E-4	.0010827	.0013707	.0020183	.0027683
.062	60	1.3634E-4	4.8981E-4	9.4303E-4	.0012042	.0017882	.0024515
.062	70	1.0051E-4	3.9362E-4	7.9404E-4	.0010292	.0015557	.0021443
.062	80	6.233E-5	2.9172E-4	6.381E-4	8.4817E-4	.0013239	.0018529
.062	90	2.2784E-5	1.8609E-4	4.7711E-4	6.6231E-4	.0010924	.0015758
.062	100	-1.7122E-5	7.8695E-5	3.1282E-4	4.7257E-4	8.5848E-4	.0013064
.062	110	-5.6408E-5	-2.8595E-5	1.4722E-4	2.8027E-4	6.1972E-4	.0010348
.062	120	-9.4067E-5	-1.3293E-4	-1.725E-5	8.7711E-5	3.7539E-4	7.5202E-4
.062	130	-1.2913E-4	-2.3518E-4	-1.7782E-4	-1.018E-4	1.2915E-4	4.5465E-4
.062	140	-1.6066E-4	-3.3062E-4	-3.3177E-4	-2.844E-4	-1.1581E-4	1.4682E-4
.063	-50	2.0289E-4	6.4007E-4	.0011152	.0013659	.0018974	.002481
.063	-40	2.4299E-4	7.7698E-4	.0013799	.0017096	.0024342	.0032616
.063	-30	2.7521E-4	8.852E-4	.0015872	.0019779	.0028523	.0038691
.063	-20	2.9867E-4	9.6244E-4	.001733	.0021659	.0031436	.0042912
.063	-10	3.1285E-4	.0018231	.0018177	.0022744	.0033104	.0045321
.063	0	3.1757E-4	.0018229	.0018447	.0023023	.0033629	.0046075
.063	10	3.1295E-4	.0018039	.0018199	.0022777	.0033162	.004541
.063	20	2.9939E-4	9.6862E-4	.0017503	.002151	.003188	.0043596
.063	30	2.7752E-4	9.0531E-4	.0016424	.0020594	.0029969	.0040919
.063	40	2.4818E-4	8.2222E-4	.0015056	.0018931	.0027606	.0037654
.063	50	2.1232E-4	7.2235E-4	.0013454	.0017008	.0024942	.0034045
.063	60	1.7106E-4	6.0935E-4	.0011634	.0014397	.0022059	.0030223
.063	70	1.2556E-4	4.867E-4	9.7656E-4	.0012652	.0019159	.0025521
.063	80	7.7068E-5	3.5635E-4	7.7524E-4	.0010311	.0016166	.0022816
.063	90	2.6948E-5	2.2064E-4	5.6902E-4	7.9017E-4	.0013136	.0019181
.063	100	-2.3309E-5	8.3023E-5	3.5632E-4	5.446E-4	.0010066	.0015575
.063	110	-7.3609E-5	-5.42E-5	1.4367E-4	2.9718E-4	6.5528E-4	.0011935
.063	120	-1.2127E-4	-1.9257E-4	-6.676E-5	5.0808E-5	3.8098E-4	8.2104E-4
.063	130	-1.6554E-4	-3.1755E-4	-2.716E-4	-1.9028E-4	6.7635E-5	4.3973E-4
.063	140	-2.052E-4	-4.3869E-4	-4.677E-4	-4.2215E-4	-2.3811E-4	5.6083E-5

Table 3.5

(continued)

 $\delta B(\theta, E_{\text{eff}})$

BIN	TH	E= .25	E= .75	E= 1.25	E= 1.5	E= 2.0	E= 2.5
.064	-50	2.4419E-4	7.7234E-4	.0013511	.0016589	.0023133	.0030282
.064	-40	2.9211E-4	9.3331E-4	.0016559	.0020499	.0029101	.0038784
.064	-30	3.3063E-4	.0010607	.0018944	.0023549	.0033733	.0045358
.064	-20	3.527E-4	.0011518	.0020626	.0025687	.0036955	.0049528
.064	-10	3.7562E-4	.0012058	.0021606	.0026925	.0038863	.0052501
.064	0	3.8134E-4	.0012234	.002192	.0027319	.0039386	.0053214
.064	10	3.7578E-4	.0012067	.002163	.0026959	.0038861	.005259
.064	20	3.5947E-4	.0011585	.002081	.002595	.0037414	.0050608
.064	30	3.3314E-4	.0010825	.0019542	.0024405	.0035236	.0047656
.064	40	2.9777E-4	9.8232E-4	.0017506	.0022433	.0032506	.0044008
.064	50	2.5452E-4	8.6196E-4	.0015977	.0020131	.0029356	.0039908
.064	60	2.0471E-4	7.2518E-4	.001332	.0017583	.0022605	.0035556
.064	70	1.4977E-4	5.7566E-4	.0011492	.0014855	.0022452	.0031092
.064	80	9.115E-5	4.169E-4	9.04E-4	.0011997	.0018802	.0026618
.064	90	3.053E-5	2.5228E-4	6.5047E-4	9.0524E-4	.0015082	.0022147
.064	100	-3.0632E-5	8.5067E-5	3.9245E-4	6.0553E-4	.0011315	.0017673
.064	110	-9.0713E-5	-8.1545E-5	1.3375E-4	3.0426E-4	7.5092E-4	.0013165
.064	120	-1.4814E-4	-2.444E-4	-1.2175E-4	5.4644E-4	3.6948E-4	8.6013E-4
.064	130	-2.0139E-4	-4.0038E-4	-3.700E-4	-2.8632E-4	-7.7927E-4	4.0029E-4
.064	140	-2.4896E-4	-5.4635E-4	-6.074E-4	-5.6668E-4	-3.7404E-4	-5.5516E-5
.065	-50	2.8402E-4	8.9889E-4	.0015746	.0019346	.0027003	.0035325
.065	-40	3.3949E-4	.001083	.0019175	.0023707	.0033539	.0044476
.065	-30	3.841E-4	.0012288	.002186	.0027107	.00386	.0051521
.065	-20	4.1663E-4	.0013333	.0023757	.0029454	.004212	.0056389
.065	-10	4.3633E-4	.0013953	.0024864	.0030879	.0044142	.0059163
.065	0	4.429E-4	.0014155	.002522	.0031321	.0044781	.0060034
.065	10	4.3645E-4	.0013962	.0024838	.0030914	.0044202	.0059255
.065	20	4.1748E-4	.0013404	.0023948	.0029767	.0042595	.0057109
.065	30	3.8684E-4	.001252	.0022487	.0028001	.0040154	.0053885
.065	40	3.4564E-4	.0011354	.0020593	.0025731	.0037068	.0049559
.065	50	2.9522E-4	9.9489E-4	.0018349	.0023064	.0032505	.0045277
.065	60	2.3713E-4	8.3492E-4	.0015929	.0020094	.0029604	.0040346
.065	70	1.7302E-4	6.5981E-4	.0013101	.0016899	.0025474	.0035219
.065	80	1.0466E-4	4.7373E-4	.0010221	.0013544	.0021193	.0029998
.065	90	3.3872E-5	2.8072E-4	7.2427E-4	.0010091	.0016814	.0024734
.065	100	-3.7407E-5	9.4007E-5	4.2122E-4	6.5599E-4	.0012372	.0019441
.065	110	-1.0754E-4	-1.1049E-4	1.1776E-4	3.0254E-4	7.9004E-4	.0014116
.065	120	-1.7445E-4	-3.0107E-4	-1.8164E-4	-4.7355E-4	3.4404E-4	8.7642E-4
.065	130	-2.3639E-4	-4.8325E-4	-4.7231E-4	-3.8863E-4	-9.5185E-4	3.4215E-4
.065	140	-2.9164E-4	-6.5325E-4	-7.4973E-4	-7.162E-4	-5.2059E-4	-1.8299E-4
.07	-50	4.5561E-4	.0014279	.002478	.0030295	.004185	.0054037
.07	-40	5.4373E-4	.00171	.00298	.0036521	.0050698	.0065789
.07	-30	6.1468E-4	.0019341	.0033741	.0041381	.0057533	.0074777
.07	-20	6.6652E-4	.0020953	.0036538	.004481	.00623	.0080982
.07	-10	6.9798E-4	.0021916	.0038183	.0046815	.0065056	.0084534
.07	0	7.0848E-4	.0022233	.0038717	.0047462	.0065936	.0085658
.07	10	6.9811E-4	.0021927	.003821	.0046855	.0065122	.0084633
.07	20	6.6757E-4	.002104	.0036759	.0045124	.0062825	.00821762
.07	30	6.1808E-4	.0019625	.0034473	.0042412	.0059264	.0077348
.07	40	5.5139E-4	.0017741	.0031468	.0038967	.0054655	.0071683
.07	50	4.6961E-4	.0015457	.0027362	.0034634	.0049202	.0065036
.07	60	3.752E-4	.0012841	.0023768	.0029848	.004309	.0057643
.07	70	2.7087E-4	9.9539E-4	.0019295	.0024638	.0036482	.0049707
.07	80	1.5954E-4	6.8971E-4	.0014545	.0019117	.0029519	.0041394
.07	90	4.4244E-5	3.7104E-4	9.6121E-4	.0013391	.0022323	.003284
.07	100	-7.1891E-5	4.7361E-5	4.5873E-4	7.5531E-4	.0014997	.002415
.07	110	-1.8572E-4	-2.7444E-4	-4.4203E-4	1.7077E-4	7.637E-4	.0015414
.07	120	-2.9413E-4	-5.8749E-4	-5.3933E-4	-4.0718E-4	3.3217E-4	6.7154E-4
.07	130	-3.9408E-4	-8.8485E-4	-1.0010182	-9.6939E-4	-6.8271E-4	-1.2553E-4
.07	140	-4.827E-4	-1.0011595	-1.0014723	-1.0015071	-1.001375	-1.0010202
.08	-50	6.5126E-4	.0019824	.0033406	.0040274	.0054093	.0067945
.08	-40	7.7731E-4	.0023734	.0040134	.0048469	.0065338	.0082332
.08	-30	8.7896E-4	.0026851	.0045442	.0054982	.0074073	.0093484
.08	-20	9.5338E-4	.0029106	.0049236	.0059475	.0080218	.010122
.08	-10	9.9864E-4	.0030459	.0051459	.0062175	.0083309	.010569
.08	0	.0010139	.0030906	.0052227	.0063055	.0084969	.010712
.08	10	9.9878E-4	.0030468	.0051518	.0062216	.0083877	.010579
.08	20	9.5444E-4	.0029189	.0049465	.0059793	.0080748	.010199
.08	30	8.8243E-4	.0027133	.0046191	.0055946	.0075818	.0096056
.08	40	7.8511E-4	.0024379	.0041938	.005095	.0069331	.0088291
.08	50	6.6551E-4	.0021015	.0036555	.0044583	.0061523	.0079004
.08	60	5.2718E-4	.0017141	.0030497	.0037629	.0052645	.0068479
.08	70	3.7412E-4	.001226	.0023221	.0029867	.0042904	.0056982
.08	80	2.1057E-4	8.2026E-4	.0016591	.0021572	.0032516	.0044754
.08	90	4.1411E-5	3.5141E-4	9.222E-4	.0012915	.0021673	.0032012
.08	100	-1.2391E-4	-1.3259E-4	1.6271E-4	4.0621E-4	.0010577	.0018957
.08	110	-2.9551E-4	-6.1249E-4	-5.9819E-4	-4.8233E-4	-6.1272E-4	5.7701E-4
.08	120	-4.5366E-4	-1.0010767	-1.0013442	-1.0013578	-1.0011718	-7.3773E-4
.08	130	-5.9878E-4	-1.0015135	-1.0022597	-1.0022028	-1.0022569	-1.0023019
.08	140	-7.2656E-4	-1.0019113	-1.0027284	-1.0030028	-1.0032988	-1.0032888

Table 3.5

(continued)

 $\delta B(\beta_{in}, \theta, E_{eff})$

BIN	TH	E=.25	E=.75	E=1.25	E=1.5	E=2.0	E=2.5
.09	-50	7.015E-4	.0020938	.0034662	.0041432	.0054743	.0057716
.09	-40	8.3771E-4	.0025107	.0041743	.0050007	.0066381	.0082514
.09	-30	9.4765E-4	.0028443	.004726	.0056779	.0075434	.0094004
.09	-20	.0010283	.0030866	.0051401	.0061629	.0081963	.010209
.09	-10	.0010774	.0032327	.0053817	.0064516	.0085781	.010683
.09	0	.0010939	.0032813	.0054613	.0065463	.0087025	.010836
.09	10	.0010776	.0032336	.0053841	.0064548	.0085837	.010691
.09	20	.0010292	.0030937	.0051583	.006189	.0082433	.010274
.09	30	9.5048E-4	.0028677	.0047573	.0057636	.0076941	.0096157
.09	40	8.4396E-4	.0025636	.0043134	.0051957	.0069697	.0087448
.09	50	7.1229E-4	.0021988	.0037228	.0045039	.0060284	.0076925
.09	60	5.6116E-4	.0017631	.003042	.0037076	.0050724	.0064827
.09	70	3.9318E-4	.0012832	.0022387	.0028272	.0039633	.0051627
.09	80	2.1379E-4	7.7245E-4	.0014811	.0018829	.0027678	.0037425
.09	90	2.812E-5	2.4099E-4	6.3759E-4	8.9571E-4	.0015162	.0022553
.09	100	-1.5852E-4	-2.9779E-4	-2.2272E-4	-1.1357E-4	2.3243E-4	7.27E-4
.09	110	-3.4077E-4	-8.3016E-4	-.0010806	-.0011237	-.0010597	-8.1639E-4
.09	120	-5.1334E-4	-.0013423	-.0019164	-.0021129	-.002336	-.0023515
.09	130	-6.7114E-4	-.0018203	-.0027099	-.003059	-.0035716	-.0032511
.09	140	-8.0942E-4	-.0022505	-.0034406	-.0039328	-.0047405	-.0052889
.1	-50	6.7545E-4	.0019973	.0032788	.0039041	.0051217	.0052946
.1	-40	8.0669E-4	.0023962	.0039522	.0047171	.0062193	.0076838
.1	-30	9.1276E-4	.0027163	.0044888	.0053628	.007085	.0083772
.1	-20	9.906E-4	.0029495	.0048768	.0058221	.0077045	.0095453
.1	-10	.0010381	.0030907	.0051101	.0061068	.008073	.010032
.1	0	.001054	.0031378	.0051374	.0061968	.0081939	.010151
.1	10	.0010381	.0030914	.0051119	.0061092	.0080772	.010009
.1	20	9.9112E-4	.0029548	.0048902	.0058475	.0077375	.0095948
.1	30	9.1461E-4	.0027334	.0045341	.0054264	.0071935	.0089347
.1	40	8.1099E-4	.0024346	.0040547	.0048615	.0064562	.0078555
.1	50	6.8339E-4	.0020677	.0034675	.0041704	.0055729	.0069957
.1	60	5.3562E-4	.0016432	.0027328	.0033723	.0045559	.0057547
.1	70	3.7204E-4	.0011727	.0020364	.0024876	.0034225	.004292
.1	80	1.9737E-4	6.6899E-4	.0012293	.001538	.0022048	.0029275
.1	90	1.6696E-5	1.453E-4	3.870E-4	5.4545E-4	9.2922E-4	.0013911
.1	100	-1.6474E-4	-3.8444E-4	-4.6997E-4	-4.6698E-4	-3.7726E-4	-1.873E-4
.1	110	-3.4163E-4	-9.0607E-4	-.0013208	-.0014758	-.001687	-.0017772
.1	120	-5.0879E-4	-.0014053	-.0021443	-.0024563	-.0029717	-.0033475
.1	130	-6.6122E-4	-.0018682	-.0029188	-.0033855	-.0042018	-.004866
.1	140	-7.9431E-4	-.0022809	-.0036225	-.0042366	-.0053469	-.0062983
.11	-50	6.1624E-4	.0018171	.0029744	.0035379	.004632	.0056233
.11	-40	7.3594E-4	.0021793	.0035836	.0042721	.0056199	.0069297
.11	-30	8.3276E-4	.0024707	.004071	.0048579	.0064037	.0079133
.11	-20	9.0389E-4	.0026834	.0044249	.005222	.0069631	.0085176
.11	-10	9.4732E-4	.0028126	.0046386	.0055373	.007306	.0090371
.11	0	9.6191E-4	.0028557	.0047097	.005622	.0074175	.009175
.11	10	9.4737E-4	.0028129	.0046401	.0055391	.0073209	.0090347
.11	20	9.0431E-4	.0026869	.0044351	.0052953	.0069916	.0086533
.11	30	8.3412E-4	.0024822	.0041033	.0049029	.0064809	.0080302
.11	40	7.39E-4	.0022057	.0036562	.0043728	.0057951	.0071958
.11	50	6.2183E-4	.0018655	.0031071	.003725	.0049555	.006176
.11	60	4.8611E-4	.0014717	.0024718	.0029744	.003985	.0049984
.11	70	3.3583E-4	.0010352	.001767	.0021417	.0029082	.0036918
.11	80	1.7543E-4	5.6207E-4	.0010112	.0012479	.0017503	.0022862
.11	90	9.5964E-6	8.3069E-5	2.2365E-4	3.1522E-4	5.3971E-4	8.1223E-4
.11	100	-1.5679E-4	-4.0651E-4	-5.7553E-4	-6.3346E-4	-6.3717E-4	-6.9235E-4
.11	110	-3.1883E-4	-8.8711E-4	-.0013557	-.0015744	-.0019211	-.0022129
.11	120	-4.717E-4	-.0013452	-.0021258	-.0024835	-.0031325	-.0036975
.11	130	-6.1083E-4	-.0017675	-.0028349	-.0033362	-.0042709	-.0051173
.11	140	-7.3198E-4	-.0021414	-.0034724	-.0041081	-.0053153	-.0064355
.12	-50	5.4708E-4	.001613	.0026416	.0031421	.0041163	.0050541
.12	-40	6.5321E-4	.0019333	.0031788	.0037889	.0049344	.0061468
.12	-30	7.3911E-4	.0021914	.0036099	.0043067	.0055764	.00693141
.12	-20	8.0225E-4	.0023803	.0039239	.0046921	.0061771	.007639
.12	-10	8.4083E-4	.0024952	.0041141	.0049105	.0064793	.00803133
.12	0	8.5379E-4	.0025336	.0041775	.0049862	.0065782	.008137
.12	10	8.4086E-4	.0024955	.0041149	.0049118	.0064803	.00803164
.12	20	8.0253E-4	.0023828	.0039306	.0046927	.0061933	.0076638
.12	30	7.4093E-4	.0021995	.0036318	.0043378	.0057296	.0070956
.12	40	6.5528E-4	.0019515	.0032202	.0038591	.0051055	.0063321
.12	50	5.5097E-4	.0016463	.002732	.0032709	.0043395	.0053964
.12	60	4.2991E-4	.0012927	.0021574	.0025593	.003453	.0043137
.12	70	2.9599E-4	9.0084E-4	.0015201	.0018341	.0024655	.0031115
.12	80	1.5308E-4	4.8173E-4	8.3707E-4	.0010226	.0014117	.0018185
.12	90	5.4032E-6	4.7299E-5	1.2655E-4	1.792E-4	3.0751E-4	4.6501E-4
.12	100	-1.4265E-4	-3.9035E-4	-5.9259E-4	-6.7718E-4	-8.1655E-4	-9.176E-4
.12	110	-2.8673E-4	-8.157E-4	-.001331	-.0015231	-.0019326	-.0022967
.12	120	-4.2248E-4	-.0012271	-.001979	-.0023357	-.0030118	-.0035356
.12	130	-5.4583E-4	-.0016011	-.0026074	-.0030922	-.0040252	-.0049058
.12	140	-6.5302E-4	-.0019303	-.0031674	-.0037702	-.0049437	-.0060719

Table 3.5

(continued)

 $\delta\beta(\beta_{in}, \theta, E_{eff})$

BIN	TH	E= .25	E= .75	E= 1.25	E= 1.5	E= 2.0	E= 2.5
.13	-50	4.7885E-4	.0014138	.0023189	.0027606	.0036217	.0044543
.13	-40	5.716E-4	.0016932	.0027867	.0033233	.0043757	.0054017
.13	-30	6.4671E-4	.0019187	.0031629	.003775	.004979	.0061571
.13	-20	7.0155E-4	.002084	.0034377	.0041043	.0054172	.006704
.13	-10	7.3572E-4	.0021846	.0036044	.0043038	.0056818	.0070332
.13	0	7.4707E-4	.0022184	.0036602	.0043733	.0057699	.0071425
.13	10	7.3574E-4	.0021849	.003605	.0043045	.0056823	.0070356
.13	20	7.0214E-4	.0020857	.0034422	.0041186	.0054285	.0067217
.13	30	6.4734E-4	.0019242	.0031778	.0037959	.0050159	.0062142
.13	40	5.7301E-4	.0017056	.0028203	.0033708	.0044593	.0055305
.13	50	4.8142E-4	.0014364	.0023504	.002848	.0037752	.0046939
.13	60	3.7531E-4	.0011244	.0018707	.0022423	.0029228	.0037126
.13	70	2.5784E-4	7.7833E-4	.0013355	.0015703	.0021033	.0026328
.13	80	1.3251E-4	4.0938E-4	7.0037E-4	8.5031E-4	.0011594	.0014785
.13	90	3.0587E-6	2.6647E-5	7.1745E-5	1.0145E-4	1.7544E-4	2.6636E-4
.13	100	-1.2667E-4	-3.5844E-4	-5.6305E-4	-6.5612E-4	-8.2328E-4	-9.6774E-4
.13	110	-2.528E-4	-7.3477E-4	-.0011865	-.0014018	-.0018106	-.0021928
.13	120	-3.7154E-4	-.0010914	-.0017809	-.0021147	-.00276	-.003377
.13	130	-4.7932E-4	-.0014176	-.0023228	-.0027745	-.0036448	-.0044822
.13	140	-5.7284E-4	-.0017036	-.0028139	-.0033612	-.0044389	-.005494
.14	-50	4.1629E-4	.0012314	.0020235	.0024111	.0031697	.0039066
.14	-40	4.968E-4	.0014737	.0024286	.0028893	.0038213	.0047241
.14	-30	5.6202E-4	.0016694	.0027549	.0032298	.0043441	.0053783
.14	-20	6.1E-4	.0018129	.0029937	.003576	.004725	.0058537
.14	-10	6.3935E-4	.0019005	.0031389	.0037499	.0049557	.0061408
.14	0	6.4922E-4	.0019299	.0031375	.003808	.0050326	.0062363
.14	10	6.3936E-4	.0019006	.0031393	.0037504	.0049567	.0061423
.14	20	6.1013E-4	.001814	.0029968	.0035825	.0047328	.0058656
.14	30	5.6244E-4	.001673	.0027651	.0033243	.0043695	.0054174
.14	40	4.9775E-4	.001482	.0024515	.0029308	.0039787	.0048124
.14	50	4.1803E-4	.0012467	.0020654	.0024711	.0032749	.0040628
.14	60	3.2566E-4	9.7399E-4	.0016181	.0019394	.0025753	.0032071
.14	70	2.2342E-4	6.7192E-4	.0011221	.0013476	.001799	.0022503
.14	80	1.1436E-4	3.4919E-4	5.9148E-4	7.151E-4	9.6667E-4	.0012234
.14	90	1.7394E-6	1.5131E-5	4.0962E-5	5.8194E-5	1.0055E-4	1.5274E-4
.14	100	-1.1107E-4	-3.2058E-4	-5.1395E-4	-6.0495E-4	-7.7625E-4	-9.34E-4
.14	110	-2.2069E-4	-6.4813E-4	-.0010576	-.0012558	-.00164	-.0020023
.14	120	-3.222E-4	-9.5709E-4	-.0015742	-.0018752	-.0024600	-.003041
.14	130	-4.1733E-4	-.0012406	-.0020485	-.0024469	-.0032323	-.004003
.14	140	-4.9839E-4	-.0014876	-.0024662	-.0029516	-.0039142	-.0048658
.15	-50	3.6098E-4	.0010698	.0017617	.0021003	.0027672	.0034166
.15	-40	4.3069E-4	.0012794	.0021118	.0025215	.0033296	.0041217
.15	-30	4.8719E-4	.0014468	.0023942	.0028606	.0037818	.0046874
.15	-20	5.2875E-4	.0015733	.0025011	.0030897	.0041121	.0050997
.15	-10	5.5418E-4	.0016492	.0025771	.0032596	.0043126	.0053495
.15	0	5.6274E-4	.0016747	.0025692	.0033101	.0043795	.0054329
.15	10	5.5419E-4	.0016493	.0025722	.00326	.0043132	.0053503
.15	20	5.2884E-4	.001574	.002503	.0031117	.0041175	.0051085
.15	30	4.8746E-4	.0014514	.0024208	.0029705	.0037994	.0047152
.15	40	4.3133E-4	.0012851	.002127	.002544	.0033691	.0041836
.15	50	3.6215E-4	.0010802	.0017898	.0021419	.0028396	.0035296
.15	60	2.82E-4	8.4285E-4	.0013991	.001676	.0022258	.0027716
.15	70	1.9329E-4	5.7992E-4	9.6602E-4	.0011594	.001545	.0019302
.15	80	9.8676E-5	2.5914E-4	5.03E-4	6.0672E-4	8.1572E-4	.001028
.15	90	9.9819E-7	8.6961E-6	2.3172E-5	3.3464E-5	5.8073E-5	8.9032E-5
.15	100	-9.6812E-5	-2.8291E-4	-4.557E-4	-5.4423E-4	-7.0729E-4	-8.6152E-4
.15	110	-1.9181E-4	-5.6708E-4	-9.319E-4	-.0011099	-.001459	-.0017979
.15	120	-2.8114E-4	-8.3538E-4	-.0013795	-.0016472	-.0021757	-.0026941
.15	130	-3.6209E-4	-.0010798	-.0017391	-.0021402	-.0028365	-.0035241
.15	140	-4.3219E-4	-.0012928	-.0021484	-.0025738	-.0034213	-.004263

Table 3.6

t_{out} as a function
of β_{in} , θ , and E_{eff}

t_{out}								
BIN	TH	E= .25	E= .75	E= 1.25	E= 1.5	E= 2.0	E= 2.5	
.06	-50	2.2465E-8	2.2232E-8	2.1971E-8	2.1837E-8	2.1669E-8	2.1301E-8	
.06	-40	2.2477E-8	2.2253E-8	2.1995E-8	2.1859E-8	2.1689E-8	2.1275E-8	
.06	-30	2.249E-8	2.2281E-8	2.2024E-8	2.1885E-8	2.1714E-8	2.1291E-8	
.06	-20	2.2504E-8	2.2318E-8	2.2075E-8	2.1932E-8	2.1758E-8	2.1340E-8	
.06	-10	2.2521E-8	2.2362E-8	2.2135E-8	2.2011E-8	2.1733E-8	2.1435E-8	
.06	0	2.2535E-8	2.2411E-8	2.2212E-8	2.2096E-8	2.1837E-8	2.1555E-8	
.06	10	2.2557E-8	2.2464E-8	2.2258E-8	2.2132E-8	2.1953E-8	2.1699E-8	
.06	20	2.2576E-8	2.2515E-8	2.2353E-8	2.2225E-8	2.2051E-8	2.1865E-8	
.06	30	2.2555E-8	2.2574E-8	2.2473E-8	2.2402E-8	2.2231E-8	2.2035E-8	
.06	40	2.2612E-8	2.2629E-8	2.2563E-8	2.2502E-8	2.2374E-8	2.2212E-8	
.06	50	2.263E-8	2.266E-8	2.265E-8	2.2614E-8	2.2514E-8	2.2395E-8	
.06	60	2.2644E-8	2.2726E-8	2.2738E-8	2.2714E-8	2.2649E-8	2.256E-8	
.06	70	2.2657E-8	2.2771E-8	2.2805E-8	2.2807E-8	2.2775E-8	2.272E-8	
.06	80	2.2667E-8	2.2802E-8	2.2879E-8	2.2891E-8	2.289E-8	2.2866E-8	
.06	90	2.2675E-8	2.284E-8	2.2935E-8	2.2966E-8	2.2993E-8	2.2926E-8	
.06	100	2.2675E-8	2.2866E-8	2.2959E-8	2.3031E-8	2.3084E-8	2.311E-8	
.06	110	2.268E-8	2.2879E-8	2.303E-8	2.3085E-8	2.3162E-8	2.3205E-8	
.06	120	2.2677E-8	2.2896E-8	2.3059E-8	2.3126E-8	2.3229E-8	2.3293E-8	
.06	130	2.2672E-8	2.2894E-8	2.3075E-8	2.3155E-8	2.326E-8	2.3306E-8	
.06	140	2.2663E-8	2.2872E-8	2.3077E-8	2.3168E-8	2.3317E-8	2.3425E-8	
.061	-50	2.2091E-8	2.1849E-8	2.1584E-8	2.1447E-8	2.1172E-8	2.0899E-8	
.061	-40	2.21E-8	2.1865E-8	2.1603E-8	2.1463E-8	2.1174E-8	2.0976E-8	
.061	-30	2.2111E-8	2.1897E-8	2.164E-8	2.15E-8	2.1206E-8	2.09E-8	
.061	-20	2.2125E-8	2.1934E-8	2.1682E-8	2.1557E-8	2.1257E-8	2.0959E-8	
.061	-10	2.2142E-8	2.1978E-8	2.1759E-8	2.1631E-8	2.1352E-8	2.1055E-8	
.061	0	2.216E-8	2.2028E-8	2.1834E-8	2.1718E-8	2.146E-8	2.1175E-8	
.061	10	2.2179E-8	2.2082E-8	2.1915E-8	2.1817E-8	2.1593E-8	2.132E-8	
.061	20	2.2199E-8	2.2139E-8	2.2003E-8	2.1922E-8	2.1718E-8	2.1482E-8	
.061	30	2.2218E-8	2.2195E-8	2.2101E-8	2.2031E-8	2.186E-8	2.1657E-8	
.061	40	2.2237E-8	2.2252E-8	2.2193E-8	2.2142E-8	2.2005E-8	2.1826E-8	
.061	50	2.2255E-8	2.2306E-8	2.2284E-8	2.225E-8	2.2148E-8	2.2015E-8	
.061	60	2.2271E-8	2.2357E-8	2.237E-8	2.2353E-8	2.2237E-8	2.218E-8	
.061	70	2.228E-8	2.2403E-8	2.245E-8	2.245E-8	2.2417E-8	2.2353E-8	
.061	80	2.2297E-8	2.2444E-8	2.2527E-8	2.2539E-8	2.2539E-8	2.2505E-8	
.061	90	2.2306E-8	2.2473E-8	2.2537E-8	2.2519E-8	2.2547E-8	2.254E-8	
.061	100	2.2312E-8	2.2504E-8	2.2641E-8	2.2637E-8	2.2744E-8	2.2765E-8	
.061	110	2.2314E-8	2.2521E-8	2.2654E-8	2.2744E-8	2.2829E-8	2.2873E-8	
.061	120	2.2313E-8	2.253E-8	2.2714E-8	2.2782E-8	2.2893E-8	2.2963E-8	
.061	130	2.2309E-8	2.2523E-8	2.273E-8	2.2817E-8	2.2954E-8	2.3046E-8	
.061	140	2.2301E-8	2.2517E-8	2.2731E-8	2.2829E-8	2.2993E-8	2.3113E-8	
.062	-50	2.1727E-8	2.1477E-8	2.121E-8	2.1072E-8	2.0794E-8	2.0518E-8	
.062	-40	2.1735E-8	2.1494E-8	2.1227E-8	2.1085E-8	2.0795E-8	2.05E-8	
.062	-30	2.1745E-8	2.1521E-8	2.1262E-8	2.1122E-8	2.0823E-8	2.0523E-8	
.062	-20	2.1755E-8	2.1557E-8	2.1313E-8	2.1178E-8	2.0869E-8	2.0593E-8	
.062	-10	2.1775E-8	2.16E-8	2.1378E-8	2.1251E-8	2.0975E-8	2.067E-8	
.062	0	2.1793E-8	2.165E-8	2.1454E-8	2.1329E-8	2.1051E-8	2.0753E-8	
.062	10	2.1812E-8	2.1734E-8	2.1533E-8	2.1438E-8	2.1205E-8	2.0945E-8	
.062	20	2.1832E-8	2.1762E-8	2.163E-8	2.1544E-8	2.1341E-8	2.110E-8	
.062	30	2.1852E-8	2.182E-8	2.1725E-8	2.1656E-8	2.1484E-8	2.128E-8	
.062	40	2.1872E-8	2.1875E-8	2.182E-8	2.1768E-8	2.1632E-8	2.146E-8	
.062	50	2.1891E-8	2.1936E-8	2.1914E-8	2.186E-8	2.172E-8	2.1642E-8	
.062	60	2.1909E-8	2.195E-8	2.2004E-8	2.1989E-8	2.1921E-8	2.181E-8	
.062	70	2.1925E-8	2.204E-8	2.2029E-8	2.202E-8	2.2057E-8	2.1929E-8	
.062	80	2.1932E-8	2.2084E-8	2.2163E-8	2.2184E-8	2.2184E-8	2.2147E-8	
.062	90	2.1943E-8	2.2121E-8	2.2235E-8	2.2269E-8	2.23E-8	2.225E-8	
.062	100	2.1956E-8	2.2151E-8	2.2293E-8	2.2343E-8	2.2404E-8	2.2425E-8	
.062	110	2.1955E-8	2.2171E-8	2.234E-8	2.2405E-8	2.2495E-8	2.2542E-8	
.062	120	2.196E-8	2.2183E-8	2.2374E-8	2.2452E-8	2.2572E-8	2.2646E-8	
.062	130	2.1957E-8	2.2184E-8	2.2373E-8	2.2484E-8	2.2632E-8	2.2734E-8	
.062	140	2.195E-8	2.2175E-8	2.2366E-8	2.2492E-8	2.2673E-8	2.2804E-8	
.063	-50	2.1375E-8	2.1119E-8	2.0842E-8	2.0711E-8	2.0434E-8	2.0152E-8	
.063	-40	2.1382E-8	2.1133E-8	2.0865E-8	2.0722E-8	2.0432E-8	2.0133E-8	
.063	-30	2.1391E-8	2.1155E-8	2.0895E-8	2.0755E-8	2.0465E-8	2.0159E-8	
.063	-20	2.1404E-8	2.1171E-8	2.0942E-8	2.0802E-8	2.0521E-8	2.021E-8	
.063	-10	2.142E-8	2.1234E-8	2.1026E-8	2.0897E-8	2.0635E-8	2.031E-8	
.063	0	2.1437E-8	2.1282E-8	2.1031E-8	2.0966E-8	2.071E-8	2.043E-8	
.063	10	2.1457E-8	2.1337E-8	2.1166E-8	2.1064E-8	2.0822E-8	2.057E-8	
.063	20	2.1477E-8	2.1395E-8	2.1263E-8	2.1171E-8	2.0968E-8	2.0734E-8	
.063	30	2.1492E-8	2.1455E-8	2.1354E-8	2.124E-8	2.112E-8	2.092E-8	
.063	40	2.1515E-8	2.1515E-8	2.1451E-8	2.1353E-8	2.1251E-8	2.109E-8	
.063	50	2.1535E-8	2.157E-8	2.1543E-8	2.1514E-8	2.1411E-8	2.127E-8	
.063	60	2.1557E-8	2.1632E-8	2.1643E-8	2.162E-8	2.1558E-8	2.1454E-8	
.063	70	2.1574E-8	2.1674E-8	2.1731E-8	2.1733E-8	2.17E-8	2.1622E-8	
.063	80	2.1589E-8	2.1732E-8	2.1814E-8	2.182E-8	2.1833E-8	2.1774E-8	
.063	90	2.1601E-8	2.1773E-8	2.1872E-8	2.1892E-8	2.1936E-8	2.194E-8	
.063	100	2.161E-8	2.1806E-8	2.1951E-8	2.2002E-8	2.2067E-8	2.2053E-8	
.063	110	2.1615E-8	2.182E-8	2.2002E-8	2.2063E-8	2.2165E-8	2.2215E-8	
.063	120	2.1617E-8	2.1845E-8	2.204E-8	2.2123E-8	2.2248E-8	2.2327E-8	
.063	130	2.1615E-8	2.1845E-8	2.204E-8	2.2157E-8	2.2313E-8	2.2422E-8	
.063	140	2.1609E-8	2.1842E-8	2.2066E-8	2.2174E-8	2.2357E-8	2.2492E-8	

Table 3.6
(continued)
 $t_{out}(B_{in}, 0, E_{eff})$

BIN	TH	E=.25	E=.75	E=1.25	E=1.5	E=2.0	E=2.5
.064	-50	2.1035E-8	2.0775E-8	2.0504E-8	2.0366E-8	2.0085E-8	1.9815E-8
.064	-40	2.1041E-8	2.0785E-8	2.0513E-8	2.0372E-8	2.0084E-8	1.9753E-8
.064	-30	2.1045E-8	2.0807E-8	2.0541E-8	2.0401E-8	2.011E-8	1.9811E-8
.064	-20	2.1061E-8	2.0839E-8	2.0586E-8	2.0451E-8	2.0165E-8	1.9867E-8
.064	-10	2.1076E-8	2.0879E-8	2.0647E-8	2.0519E-8	2.024E-8	1.9955E-8
.064	0	2.1093E-8	2.0927E-8	2.072E-8	2.0593E-8	2.0343E-8	2.0072E-8
.064	10	2.1113E-8	2.0981E-8	2.0804E-8	2.07E-8	2.0465E-8	2.0213E-8
.064	20	2.1133E-8	2.1039E-8	2.0869E-8	2.0807E-8	2.0604E-8	2.0372E-8
.064	30	2.1154E-8	2.11E-8	2.0955E-8	2.092E-8	2.074E-8	2.0545E-8
.064	40	2.1176E-8	2.1161E-8	2.1091E-8	2.1037E-8	2.089E-8	2.072E-8
.064	50	2.1197E-8	2.1223E-8	2.1191E-8	2.1155E-8	2.1051E-8	2.0912E-8
.064	60	2.1216E-8	2.1282E-8	2.1283E-8	2.1271E-8	2.1201E-8	2.1056E-8
.064	70	2.1234E-8	2.1338E-8	2.1351E-8	2.1382E-8	2.1345E-8	2.1275E-8
.064	80	2.125E-8	2.1389E-8	2.1469E-8	2.1487E-8	2.1487E-8	2.1447E-8
.064	90	2.1264E-8	2.1432E-8	2.1546E-8	2.1582E-8	2.1616E-8	2.1603E-8
.064	100	2.1274E-8	2.1469E-8	2.1614E-8	2.1667E-8	2.1733E-8	2.1753E-8
.064	110	2.128E-8	2.1497E-8	2.1671E-8	2.1739E-8	2.1833E-8	2.1893E-8
.064	120	2.1294E-8	2.1515E-8	2.1713E-8	2.1797E-8	2.1927E-8	2.2012E-8
.064	130	2.1293E-8	2.1522E-8	2.1741E-8	2.1837E-8	2.1995E-8	2.2114E-8
.064	140	2.1279E-8	2.1519E-8	2.1751E-8	2.1852E-8	2.2047E-8	2.2195E-8
.065	-50	2.0707E-8	2.0443E-8	2.0172E-8	2.0035E-8	1.9761E-8	1.949E-8
.065	-40	2.0711E-8	2.0451E-8	2.0177E-8	2.0036E-8	1.9751E-8	1.9464E-8
.065	-30	2.0719E-8	2.0469E-8	2.0201E-8	2.0061E-8	1.9773E-8	1.9475E-8
.065	-20	2.073E-8	2.0498E-8	2.0242E-8	2.0107E-8	1.9825E-8	1.9529E-8
.065	-10	2.0744E-8	2.0537E-8	2.03E-8	2.0172E-8	1.99E-8	1.9614E-8
.065	0	2.0761E-8	2.0583E-8	2.0371E-8	2.0253E-8	1.9959E-8	1.9727E-8
.065	10	2.078E-8	2.0636E-8	2.0453E-8	2.0342E-8	2.0117E-8	1.9864E-8
.065	20	2.08E-8	2.0694E-8	2.0544E-8	2.0454E-8	2.025E-8	2.0021E-8
.065	30	2.0822E-8	2.0755E-8	2.0641E-8	2.0567E-8	2.0394E-8	2.0193E-8
.065	40	2.0843E-8	2.0818E-8	2.0741E-8	2.0685E-8	2.0544E-8	2.0372E-8
.065	50	2.0865E-8	2.0861E-8	2.084E-8	2.0805E-8	2.0685E-8	2.0553E-8
.065	60	2.0885E-8	2.0942E-8	2.0946E-8	2.0923E-8	2.0855E-8	2.0746E-8
.065	70	2.0904E-8	2.1E-8	2.1038E-8	2.1038E-8	2.1005E-8	2.093E-8
.065	80	2.0921E-8	2.1054E-8	2.1129E-8	2.1147E-8	2.1147E-8	2.1107E-8
.065	90	2.0936E-8	2.1101E-8	2.1212E-8	2.1248E-8	2.1292E-8	2.1275E-8
.065	100	2.0947E-8	2.1141E-8	2.1255E-8	2.1332E-8	2.1406E-8	2.1431E-8
.065	110	2.0955E-8	2.1172E-8	2.1346E-8	2.1415E-8	2.1517E-8	2.1574E-8
.065	120	2.0965E-8	2.1193E-8	2.1393E-8	2.1477E-8	2.1611E-8	2.17E-8
.065	130	2.0966E-8	2.1204E-8	2.1425E-8	2.1523E-8	2.1697E-8	2.1803E-8
.065	140	2.0957E-8	2.1203E-8	2.1439E-8	2.1548E-8	2.1741E-8	2.1855E-8
.07	-50	1.9216E-8	1.8955E-8	1.8697E-8	1.857E-8	1.8321E-8	1.8072E-8
.07	-40	1.9215E-8	1.8949E-8	1.8682E-8	1.855E-8	1.8297E-8	1.8023E-8
.07	-30	1.9217E-8	1.8954E-8	1.8687E-8	1.8552E-8	1.8284E-8	1.8015E-8
.07	-20	1.9224E-8	1.8971E-8	1.871E-8	1.8577E-8	1.831E-8	1.8043E-8
.07	-10	1.9234E-8	1.8992E-8	1.8755E-8	1.8623E-8	1.8364E-8	1.8102E-8
.07	0	1.9242E-8	1.9036E-8	1.8806E-8	1.8687E-8	1.8441E-8	1.819E-8
.07	10	1.9264E-8	1.9081E-8	1.8876E-8	1.8766E-8	1.8541E-8	1.8324E-8
.07	20	1.9293E-8	1.9133E-8	1.8959E-8	1.8862E-8	1.8656E-8	1.8444E-8
.07	30	1.9334E-8	1.9192E-8	1.9049E-8	1.8958E-8	1.879E-8	1.8597E-8
.07	40	1.9386E-8	1.9254E-8	1.9147E-8	1.9082E-8	1.8935E-8	1.8767E-8
.07	50	1.9348E-8	1.9315E-8	1.925E-8	1.9202E-8	1.9087E-8	1.8945E-8
.07	60	1.9371E-8	1.9324E-8	1.9254E-8	1.9226E-8	1.9245E-8	1.9137E-8
.07	70	1.9392E-8	1.9442E-8	1.9455E-8	1.9445E-8	1.9424E-8	1.9325E-8
.07	80	1.9413E-8	1.9509E-8	1.9561E-8	1.957E-8	1.9561E-8	1.95E-8
.07	90	1.9431E-8	1.9567E-8	1.9657E-8	1.9695E-8	1.9714E-8	1.9787E-8
.07	100	1.9447E-8	1.9618E-8	1.9746E-8	1.9793E-8	1.9855E-8	1.9925E-8
.07	110	1.946E-8	1.9661E-8	1.9824E-8	1.989E-8	1.9992E-8	2.0055E-8
.07	120	1.947E-8	1.9696E-8	1.989E-8	1.9973E-8	2.011E-8	2.0205E-8
.07	130	1.9476E-8	1.9721E-8	1.9941E-8	2.0039E-8	2.0205E-8	2.0343E-8
.07	140	1.9477E-8	1.9734E-8	1.9975E-8	2.0086E-8	2.0287E-8	2.0455E-8
.08	-50	1.6822E-8	1.6617E-8	1.6421E-8	1.6327E-8	1.6145E-8	1.5972E-8
.08	-40	1.6815E-8	1.6595E-8	1.6392E-8	1.629E-8	1.6091E-8	1.5891E-8
.08	-30	1.6812E-8	1.6583E-8	1.6382E-8	1.6284E-8	1.6084E-8	1.5884E-8
.08	-20	1.6812E-8	1.6582E-8	1.6357E-8	1.6247E-8	1.6025E-8	1.5824E-8
.08	-10	1.6815E-8	1.659E-8	1.6366E-8	1.6256E-8	1.6045E-8	1.5835E-8
.08	0	1.6822E-8	1.6608E-8	1.6395E-8	1.628E-8	1.6069E-8	1.5877E-8
.08	10	1.6832E-8	1.6635E-8	1.6437E-8	1.6337E-8	1.6135E-8	1.5943E-8
.08	20	1.6844E-8	1.6671E-8	1.6491E-8	1.64E-8	1.621E-8	1.602E-8
.08	30	1.686E-8	1.6713E-8	1.6557E-8	1.647E-8	1.6311E-8	1.6143E-8
.08	40	1.6877E-8	1.6762E-8	1.6632E-8	1.6564E-8	1.6421E-8	1.6272E-8
.08	50	1.6896E-8	1.6815E-8	1.6717E-8	1.663E-8	1.6544E-8	1.6417E-8
.08	60	1.6915E-8	1.6872E-8	1.6805E-8	1.6767E-8	1.6677E-8	1.6575E-8
.08	70	1.6938E-8	1.693E-8	1.69E-8	1.6877E-8	1.6816E-8	1.6743E-8
.08	80	1.6956E-8	1.6929E-8	1.6956E-8	1.699E-8	1.696E-8	1.6918E-8
.08	90	1.6975E-8	1.7047E-8	1.7091E-8	1.7103E-8	1.711E-8	1.7066E-8
.08	100	1.6993E-8	1.7101E-8	1.7182E-8	1.7213E-8	1.7255E-8	1.7274E-8
.08	110	1.7009E-8	1.7152E-8	1.7263E-8	1.7317E-8	1.7394E-8	1.7447E-8
.08	120	1.7023E-8	1.7195E-8	1.7246E-8	1.7412E-8	1.7525E-8	1.7612E-8
.08	130	1.7034E-8	1.7223E-8	1.741E-8	1.7495E-8	1.7642E-8	1.7764E-8
.08	140	1.7041E-8	1.7221E-8	1.7467E-8	1.7563E-8	1.7742E-8	1.7892E-8

Table 3.6

(continued)

 $t_{out}(E_{in}, 0, E_{eff})$

PIN	TH	E=.25	E=.75	E=1.25	E=1.5	E=2.0	E=2.5
.09	-50	1.4973E-8	1.483E-8	1.4655E-8	1.4631E-8	1.4509E-8	1.4392E-8
.09	-40	1.4964E-8	1.4804E-8	1.4652E-8	1.4578E-8	1.4438E-8	1.4304E-8
.09	-30	1.4958E-8	1.4786E-8	1.4621E-8	1.4541E-8	1.4393E-8	1.4241E-8
.09	-20	1.4955E-8	1.4775E-8	1.4603E-8	1.4519E-8	1.4362E-8	1.4203E-8
.09	-10	1.4954E-8	1.4773E-8	1.4593E-8	1.4513E-8	1.4349E-8	1.4195E-8
.09	0	1.4956E-8	1.4775E-8	1.4592E-8	1.4502E-8	1.4337E-8	1.4182E-8
.09	10	1.4961E-8	1.4792E-8	1.4602E-8	1.4545E-8	1.4385E-8	1.423E-8
.09	20	1.4969E-8	1.4813E-8	1.4603E-8	1.4582E-8	1.4431E-8	1.4282E-8
.09	30	1.4979E-8	1.484E-8	1.4701E-8	1.4631E-8	1.4452E-8	1.4354E-8
.09	40	1.4991E-8	1.4874E-8	1.4752E-8	1.4692E-8	1.4568E-8	1.4443E-8
.09	50	1.5004E-8	1.4912E-8	1.4814E-8	1.4762E-8	1.4657E-8	1.4548E-8
.09	60	1.5019E-8	1.4955E-8	1.4881E-8	1.4824E-8	1.4757E-8	1.4667E-8
.09	70	1.5035E-8	1.5E-8	1.4954E-8	1.4927E-8	1.4866E-8	1.4792E-8
.09	80	1.5051E-8	1.5049E-8	1.5035E-8	1.5017E-8	1.4982E-8	1.4937E-8
.09	90	1.5067E-8	1.5065E-8	1.5102E-8	1.5109E-8	1.5102E-8	1.5093E-8
.09	100	1.5082E-8	1.5142E-8	1.5152E-8	1.5202E-8	1.5224E-8	1.5232E-8
.09	110	1.5097E-8	1.5167E-8	1.5261E-8	1.5292E-8	1.5344E-8	1.5361E-8
.09	120	1.5111E-8	1.5223E-8	1.5331E-8	1.5377E-8	1.5455E-8	1.5526E-8
.09	130	1.5122E-8	1.5264E-8	1.5394E-8	1.5455E-8	1.5566E-8	1.5663E-8
.09	140	1.5131E-8	1.5294E-8	1.5448E-8	1.5522E-8	1.5661E-8	1.5786E-8
.1	-50	1.3493E-8	1.3397E-8	1.3305E-8	1.3266E-8	1.3185E-8	1.3105E-8
.1	-40	1.3485E-8	1.3372E-8	1.3262E-8	1.3217E-8	1.312E-8	1.3028E-8
.1	-30	1.3478E-8	1.3354E-8	1.3237E-8	1.318E-8	1.307E-8	1.2966E-8
.1	-20	1.3474E-8	1.3341E-8	1.3215E-8	1.3153E-8	1.3035E-8	1.2922E-8
.1	-10	1.3472E-8	1.3334E-8	1.3203E-8	1.3135E-8	1.3015E-8	1.2896E-8
.1	0	1.3472E-8	1.3334E-8	1.3201E-8	1.3136E-8	1.301E-8	1.2886E-8
.1	10	1.3474E-8	1.3339E-8	1.3205E-8	1.3145E-8	1.302E-8	1.289E-8
.1	20	1.3478E-8	1.335E-8	1.3226E-8	1.3165E-8	1.3045E-8	1.2922E-8
.1	30	1.3484E-8	1.3367E-8	1.3252E-8	1.3195E-8	1.3083E-8	1.2972E-8
.1	40	1.3491E-8	1.3389E-8	1.3285E-8	1.3235E-8	1.3133E-8	1.3032E-8
.1	50	1.3501E-8	1.3415E-8	1.3325E-8	1.3284E-8	1.3195E-8	1.3106E-8
.1	60	1.3511E-8	1.3446E-8	1.3376E-8	1.3341E-8	1.3267E-8	1.3192E-8
.1	70	1.3523E-8	1.3475E-8	1.343E-8	1.3404E-8	1.3348E-8	1.3285E-8
.1	80	1.3535E-8	1.3515E-8	1.3487E-8	1.3471E-8	1.3435E-8	1.3394E-8
.1	90	1.3548E-8	1.3551E-8	1.3547E-8	1.3542E-8	1.3527E-8	1.3507E-8
.1	100	1.356E-8	1.3588E-8	1.3607E-8	1.3614E-8	1.3622E-8	1.3623E-8
.1	110	1.3572E-8	1.3624E-8	1.3667E-8	1.3686E-8	1.3712E-8	1.3742E-8
.1	120	1.3584E-8	1.3657E-8	1.3727E-8	1.3755E-8	1.3791E-8	1.3826E-8
.1	130	1.3593E-8	1.3688E-8	1.3777E-8	1.382E-8	1.3869E-8	1.3917E-8
.1	140	1.3601E-8	1.3715E-8	1.3824E-8	1.3877E-8	1.3935E-8	1.4004E-8
.11	-50	1.2275E-8	1.2216E-8	1.2155E-8	1.212E-8	1.2077E-8	1.2028E-8
.11	-40	1.2272E-8	1.2196E-8	1.2124E-8	1.2089E-8	1.2022E-8	1.1955E-8
.11	-30	1.2266E-8	1.2175E-8	1.2095E-8	1.2055E-8	1.1978E-8	1.1903E-8
.11	-20	1.2262E-8	1.2166E-8	1.2074E-8	1.203E-8	1.1943E-8	1.1861E-8
.11	-10	1.2255E-8	1.2157E-8	1.206E-8	1.2013E-8	1.1921E-8	1.1832E-8
.11	0	1.2258E-8	1.2154E-8	1.2057E-8	1.2004E-8	1.191E-8	1.1818E-8
.11	10	1.2258E-8	1.2154E-8	1.2054E-8	1.2005E-8	1.191E-8	1.1818E-8
.11	20	1.226E-8	1.216E-8	1.2052E-8	1.2015E-8	1.1922E-8	1.1831E-8
.11	30	1.2264E-8	1.217E-8	1.2078E-8	1.2033E-8	1.1944E-8	1.1857E-8
.11	40	1.2269E-8	1.2184E-8	1.21E-8	1.2055E-8	1.1977E-8	1.1897E-8
.11	50	1.2275E-8	1.2202E-8	1.2127E-8	1.2082E-8	1.2002E-8	1.1947E-8
.11	60	1.2282E-8	1.2223E-8	1.2163E-8	1.2122E-8	1.2071E-8	1.2008E-8
.11	70	1.2291E-8	1.2247E-8	1.2201E-8	1.2177E-8	1.2129E-8	1.2075E-8
.11	80	1.2299E-8	1.2272E-8	1.2243E-8	1.2227E-8	1.2193E-8	1.2157E-8
.11	90	1.2309E-8	1.23E-8	1.2285E-8	1.228E-8	1.2263E-8	1.2246E-8
.11	100	1.2318E-8	1.2329E-8	1.2334E-8	1.2335E-8	1.2335E-8	1.2331E-8
.11	110	1.2327E-8	1.2356E-8	1.238E-8	1.239E-8	1.2409E-8	1.2421E-8
.11	120	1.2336E-8	1.2393E-8	1.2445E-8	1.2444E-8	1.245E-8	1.2451E-8
.11	130	1.2344E-8	1.2407E-8	1.2467E-8	1.2495E-8	1.2549E-8	1.26E-8
.11	140	1.2351E-8	1.2429E-8	1.2505E-8	1.2542E-8	1.2613E-8	1.2682E-8
.12	-50	1.1264E-8	1.1224E-8	1.1186E-8	1.1167E-8	1.1133E-8	1.1101E-8
.12	-40	1.1255E-8	1.1207E-8	1.1157E-8	1.1134E-8	1.1098E-8	1.1045E-8
.12	-30	1.1254E-8	1.1192E-8	1.1132E-8	1.1105E-8	1.105E-8	1.0997E-8
.12	-20	1.125E-8	1.1181E-8	1.1114E-8	1.1082E-8	1.102E-8	1.0959E-8
.12	-10	1.1247E-8	1.1172E-8	1.1101E-8	1.1066E-8	1.0997E-8	1.0932E-8
.12	0	1.1245E-8	1.1165E-8	1.1092E-8	1.1056E-8	1.0984E-8	1.0915E-8
.12	10	1.1245E-8	1.1166E-8	1.109E-8	1.1052E-8	1.0979E-8	1.0909E-8
.12	20	1.1246E-8	1.1169E-8	1.1093E-8	1.1056E-8	1.0984E-8	1.0913E-8
.12	30	1.1248E-8	1.1174E-8	1.1102E-8	1.1065E-8	1.0997E-8	1.0929E-8
.12	40	1.1251E-8	1.1183E-8	1.1116E-8	1.1082E-8	1.1018E-8	1.0954E-8
.12	50	1.1255E-8	1.1195E-8	1.1135E-8	1.1105E-8	1.1047E-8	1.0985E-8
.12	60	1.126E-8	1.121E-8	1.1155E-8	1.1122E-8	1.1063E-8	1.1002E-8
.12	70	1.1266E-8	1.1237E-8	1.1185E-8	1.1166E-8	1.1123E-8	1.1063E-8
.12	80	1.1273E-8	1.1246E-8	1.1217E-8	1.1202E-8	1.1172E-8	1.1145E-8
.12	90	1.1275E-8	1.1266E-8	1.125E-8	1.1242E-8	1.1234E-8	1.1224E-8
.12	100	1.1287E-8	1.1287E-8	1.1285E-8	1.1283E-8	1.1278E-8	1.1271E-8
.12	110	1.1294E-8	1.1302E-8	1.132E-8	1.1325E-8	1.1333E-8	1.134E-8
.12	120	1.13E-8	1.1325E-8	1.1354E-8	1.1366E-8	1.1389E-8	1.1409E-8
.12	130	1.1307E-8	1.1348E-8	1.1387E-8	1.1406E-8	1.1443E-8	1.1477E-8
.12	140	1.1313E-8	1.1366E-8	1.1412E-8	1.1443E-8	1.1495E-8	1.1541E-8

Table 3.6

(continued)

 $t_{out}(\beta_{in}, \theta, E_{eff})$

BIN	TH	E=.25	E=.75	E=1.25	E=1.5	E=2.0	E=2.5
.13	-50	1.0404E-8	1.0377E-8	1.0353E-8	1.0341E-8	1.0318E-8	1.0297E-8
.13	-40	1.0399E-8	1.0364E-8	1.033E-8	1.0313E-8	1.0282E-8	1.0252E-8
.13	-30	1.0395E-8	1.0352E-8	1.031E-8	1.029E-8	1.025E-8	1.0213E-8
.13	-20	1.039E-8	1.0342E-8	1.0294E-8	1.027E-8	1.0224E-8	1.018E-8
.13	-10	1.0389E-8	1.0334E-8	1.0281E-8	1.0255E-8	1.0205E-8	1.0155E-8
.13	0	1.0387E-8	1.0329E-8	1.0273E-8	1.0245E-8	1.0191E-8	1.0139E-8
.13	10	1.0387E-8	1.0327E-8	1.0265E-8	1.024E-8	1.0184E-8	1.013E-8
.13	20	1.0387E-8	1.0327E-8	1.0269E-8	1.024E-8	1.0184E-8	1.013E-8
.13	30	1.0388E-8	1.033E-8	1.0274E-8	1.0246E-8	1.0191E-8	1.0138E-8
.13	40	1.039E-8	1.0336E-8	1.0283E-8	1.0256E-8	1.0205E-8	1.0154E-8
.13	50	1.0393E-8	1.0344E-8	1.0296E-8	1.0272E-8	1.0224E-8	1.0172E-8
.13	60	1.0396E-8	1.0354E-8	1.0312E-8	1.0291E-8	1.025E-8	1.0208E-8
.13	70	1.04E-8	1.0366E-8	1.0332E-8	1.0315E-8	1.028E-8	1.0246E-8
.13	80	1.0405E-8	1.038E-8	1.0355E-8	1.0342E-8	1.0315E-8	1.0282E-8
.13	90	1.041E-8	1.0395E-8	1.0379E-8	1.0371E-8	1.0353E-8	1.0335E-8
.13	100	1.0416E-8	1.0411E-8	1.0405E-8	1.0402E-8	1.0394E-8	1.0386E-8
.13	110	1.0421E-8	1.0427E-8	1.0432E-8	1.0434E-8	1.0436E-8	1.0438E-8
.13	120	1.0426E-8	1.0443E-8	1.0458E-8	1.0465E-8	1.0479E-8	1.0491E-8
.13	130	1.0431E-8	1.0458E-8	1.0484E-8	1.0496E-8	1.052E-8	1.0543E-8
.13	140	1.0436E-8	1.0472E-8	1.0506E-8	1.0525E-8	1.0559E-8	1.0593E-8
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.14	-50	9.6643E-9	9.6473E-9	9.6313E-9	9.6236E-9	9.609E-9	9.5954E-9
.14	-40	9.6607E-9	9.6364E-9	9.6131E-9	9.6018E-9	9.58E-9	9.5592E-9
.14	-30	9.6574E-9	9.6266E-9	9.5969E-9	9.5824E-9	9.5543E-9	9.527E-9
.14	-20	9.6547E-9	9.6183E-9	9.5832E-9	9.566E-9	9.5324E-9	9.4999E-9
.14	-10	9.6524E-9	9.6117E-9	9.5722E-9	9.5529E-9	9.515E-9	9.4782E-9
.14	0	9.6509E-9	9.607E-9	9.5644E-9	9.5435E-9	9.5025E-9	9.4626E-9
.14	10	9.65E-9	9.6043E-9	9.5598E-9	9.538E-9	9.4951E-9	9.4533E-9
.14	20	9.6498E-9	9.6037E-9	9.5587E-9	9.5365E-9	9.492E-9	9.4505E-9
.14	30	9.6503E-9	9.6051E-9	9.5609E-9	9.5391E-9	9.4962E-9	9.4542E-9
.14	40	9.6515E-9	9.6086E-9	9.5665E-9	9.5457E-9	9.5046E-9	9.4643E-9
.14	50	9.6534E-9	9.614E-9	9.5752E-9	9.556E-9	9.518E-9	9.4805E-9
.14	60	9.6559E-9	9.6213E-9	9.5869E-9	9.5699E-9	9.536E-9	9.5024E-9
.14	70	9.6589E-9	9.6301E-9	9.6013E-9	9.5869E-9	9.5581E-9	9.5294E-9
.14	80	9.6623E-9	9.6402E-9	9.6178E-9	9.6066E-9	9.5839E-9	9.561E-9
.14	90	9.6661E-9	9.6514E-9	9.6362E-9	9.6284E-9	9.6126E-9	9.5964E-9
.14	100	9.6701E-9	9.6632E-9	9.6558E-9	9.6518E-9	9.6435E-9	9.6346E-9
.14	110	9.6742E-9	9.6755E-9	9.6761E-9	9.6761E-9	9.6757E-9	9.6746E-9
.14	120	9.6783E-9	9.6878E-9	9.6965E-9	9.7006E-9	9.7034E-9	9.7154E-9
.14	130	9.6822E-9	9.6996E-9	9.7164E-9	9.7246E-9	9.7405E-9	9.7557E-9
.14	140	9.6859E-9	9.7108E-9	9.7353E-9	9.7473E-9	9.7711E-9	9.7944E-9
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.15	-50	9.0226E-9	9.011E-9	9.0013E-9	8.9964E-9	8.987E-9	8.9782E-9
.15	-40	9.0197E-9	9.0029E-9	8.9868E-9	8.979E-9	8.9638E-9	8.9493E-9
.15	-30	9.0171E-9	8.995E-9	8.9736E-9	8.9622E-9	8.9428E-9	8.9231E-9
.15	-20	9.0148E-9	8.9881E-9	8.9622E-9	8.9495E-9	8.9247E-9	8.9005E-9
.15	-10	9.0129E-9	8.9825E-9	8.9529E-9	8.9383E-9	8.9099E-9	8.8822E-9
.15	0	9.0115E-9	8.9783E-9	8.9458E-9	8.9299E-9	8.8986E-9	8.868E-9
.15	10	9.0106E-9	8.9756E-9	8.9413E-9	8.924E-9	8.8914E-9	8.8589E-9
.15	20	9.0102E-9	8.9744E-9	8.9394E-9	8.9222E-9	8.8892E-9	8.8549E-9
.15	30	9.0104E-9	8.975E-9	8.9402E-9	8.923E-9	8.8892E-9	8.856E-9
.15	40	9.0111E-9	8.9771E-9	8.9436E-9	8.927E-9	8.8943E-9	8.8621E-9
.15	50	9.0124E-9	8.9807E-9	8.9495E-9	8.934E-9	8.9034E-9	8.8722E-9
.15	60	9.0141E-9	8.9858E-9	8.9578E-9	8.9439E-9	8.9162E-9	8.889E-9
.15	70	9.0163E-9	8.9922E-9	8.9682E-9	8.9563E-9	8.924E-9	8.8987E-9
.15	80	9.0188E-9	8.9997E-9	8.9805E-9	8.9703E-9	8.9516E-9	8.9333E-9
.15	90	9.0217E-9	9.0081E-9	8.9943E-9	8.9874E-9	8.9733E-9	8.959E-9
.15	100	9.0247E-9	9.0171E-9	9.0093E-9	9.0052E-9	8.9968E-9	8.9882E-9
.15	110	9.0279E-9	9.0265E-9	9.0249E-9	9.0239E-9	9.0216E-9	9.019E-9
.15	120	9.031E-9	9.0361E-9	9.0487E-9	9.0429E-9	9.0469E-9	9.0506E-9
.15	130	9.0341E-9	9.0454E-9	9.0563E-9	9.0616E-9	9.072E-9	9.082E-9
.15	140	9.0371E-9	9.0543E-9	9.0712E-9	9.0796E-9	9.0961E-9	9.1123E-9

IV. THE INTERPOLATION PROGRAM

The Speakeasy program called BOX4, which carries out the interpolations and displays the results, is listed here to facilitate modification.

```

EDITING BOX4
1.0 PROGRAM
2.0 CCM_ = 931.5
2.5 C = 2.99796E8
3.0 QBY_ = Q * EAX / A
4.0 IF (ABS(QBY_ - 1.375) .GT. 1.125) *WARNING--FIELD STRENGTH EXTRAPOLATED*
5.0 EINS_ = EIN, DELEIN = EIN
6.0 BETAIN_ = (SQRT(EINS_ * (EINS_ + 2 * A * CCM_))) / (EINS_ + A * CCM_)
7.0 IF (MAX(ABS(BETAIN_ - .105)) .GT. .045) *WARNING--ENERGY OUTSIDE RANGE*
8.0 SETBACK = INTERPLAG(QBY_, THETZER_, QEBYA_, 4)
9.0 SETBACK = INTERPLAG(BETAIN_(1), SETBACK, BIN_, 6) - THETAREF
10.0 PMAX_ = INTERPLAG(QBY_, PHIMAX_, QEBYA_, 4)
11.0 PMAX_ = INTERPLAG(BETAIN_, PMAX_, BIN_, 6)
12.0 THETSIN_ = 0, DELPHIIN
13.0 THETSIN_ = THETAREF + THETSIN_ - PMAX_ + PMAX_(1)
14.0 DELB_ = INTERPLAG(QBY_, DELBETA_, QEBYA_, 4)
15.0 DELB_ = ARRAY(15, 20: DELB_)
16.0 DELB_ = INTERPLAG(THETSIN_, DELB_, THETA_, 6)
17.0 DELB_ = ARRAY(: INTERPLAG(COLARRAY(BETAIN_), TRANSPOSE(DELB_), BIN_, 6))
18.0 BETAOUT_ = BETAIN_ + DELB_
19.0 EOUTS_ = A * CCM_ * ((1 / SORT(1 - BETAOUT_ * BETAOUT_)) - 1)
20.0 IOUTS_ = INTEGERS(2, NOELS(EOUTS_))
21.0 EOUT = EOUTS_(1)
22.0 DELEOUT = EOUTS_(IOUTS_) - EOUT
23.0 DELT_ = INTERPLAG(QBY_, PASSTIM_, QEBYA_, 4)
24.0 DELT_ = ARRAY(15, 20: DELT_)
25.0 DELT_ = INTERPLAG(THETSIN_, DELT_, THETA_, 6)
26.0 DELT_ = ARRAY(: INTERPLAG(COLARRAY(BETAIN_), TRANSPOSE(DELT_), BIN_, 6))
26.5 DELT_ = DELT_ + GAP / (BETAOUT_ * C)
27.0 TIMEOUT = DELT_(1)
28.0 DELPHOUT = DELPHIIN - 360 * 98.66 * (DELT_(IOUTS_) - DELT_(1))
28.5 EIN THETAREF GAP
29.0 SETBACK EOUT
30.0 GRAPHZ(DELEOUT: DELPHOUT)

```

BOX4 is written in standard Speakeasy^{*} with two exceptions:

1. GRAPHZ exists only in the Fedeasy enhancement, as explained in Section II above. On a graphics terminal GRAPHZ in the program may, but need not, be replaced by GRAPH to obtain a slower but smoother graph of the bunch profile.
2. An underscore has been added to the names of some internal variables to protect them from accidents.

* "The SPEAKEASY-3 Reference Manual, Level MU, IBM OS/VS Version", by Stanley Cohen and Steven C. Pieper, ANL 8000, Revision 2, Argonne National Laboratory (1977).

Newly introduced variables which may require some explanation are listed here by line number:

3.0	QBY_	the value of E_{eff} for the resonator
8.0	QEBYA_	the array of values of E_{eff} for which the tables were calculated
5.0	EINS_	arrays containing the kinetic energy of the reference particle, followed by the energies of the profile particles
19.0	EOUTS_	
6.0	BETAIN_	velocities corresponding to EINS_ and
18.0	BETAOUT_	EOUTS_
9.0	BIN_	incident velocities for the tabulated cases
13.0	THETSIN_	θ values for the reference and profile particles
16.0	THETA_	θ values for the tabulated cases
8.0	THETZER_	θ_o values for the tabulated cases
10.0	PHIMAX_	ϕ_{max} for the tabulated cases
11.0	PMAX_	interpolated values of ϕ_{max}
14.0	DELBETA_	tabulated values of $\delta\beta$
17.0	DELB_	interpolated values of $\delta\beta$
23.0	PASSTIM_	tabulated values for t_{out}
26.5	DELT_	interpolated t_{out} plus time to cross the GAP
27.0	TIMEOUT	DELT_ for the reference particle

Lagrangian interpolation consists of fitting a polynomial of degree n (the last argument in INTERPLAG) to $n+1$ points. In Speakeasy, interpolation of a two-dimensional array is carried out on each row.* The manipulation of the arrays by BOX4 to interpolate three variables is most easily understood by observing the arrangements of the arrays in Tables (3.2)-(3.6).

* Loc. cit. (Speakeasy manual) pg. 247

V. EPILOGUE

All the calculations presented here, and all the experiments and tests which were not reproduced here, were carried out in Speakeasy. The bulk of the calculations were performed during a period of about six weeks, at a cost below \$1000. I could not have done this work in any comparable time without Speakeasy. I thank Steven Pieper and Thom Grace for their invaluable help with a nonlinear differential equations linkule which is not yet part of standard Speakeasy.