"TRAJECTORY"--AN ORBIT AND ION OPTIC MATRIX PROGRAM FOR THE 184-INCH CYCLOTRON

A. C. Paul

September 1969

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"TRAJECTORY"--AN ORBIT AND ION OPTIC MATRIX PROGRAM FOR THE 184-INCH CYCLOTRON*

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ABSTRACT

TRAJECTORY is a Fortran IV program for simultaneously integrating the equations of motion of a charged particle in a magnetic field and the differential equations for the ion optic matrix representing small motion about the paraxial trajectory. The orbit calculation is carried out in the median plane with the vertical transformation matrix calculated from a Taylor-series expansion of the magnetic field off the median plane. The matrix so calculated is readily used with the ion-optic transport codes TRANSPORT[1] or OPTIK.[2] The trajectory data can be used to obtain internal target positioning for a given beam line.

INTRODUCTION

TRAJECTORY tracks charged particles (protons, positive and negative pions, etc.) in either the forward or reverse direction (Fig. 1). The particles can be started individually from a specified R, θ, and ϕ and tracked forward to find the trajectory traced by a particle leaving a target, or can be run backward so that the beam line can be extended back into the cyclotron to find the required target location. The particles can, also, be started from a rectangular array of R, ϕ(Pr) values at a fixed azimuth θ so that a slit or aperture acceptance can be determined by reverse tracking.

The program output is shown in Fig. 2 with the trajectory printed in polar and rectangular coordinates, and can be used for any cyclotron with cylindrical or rectangular geometry. It is possible to determine the target locations and meson wheel angle required for a given external beam line by properly choosing the starting location of particles to be tracked (Fig. 3).

The orbit calculation can be stopped at any desired radius, azimuth, or value of trajectory length, so that the accuracy of the matrix can be checked by comparison with the matrix determined by actual ray tracing. Also, the orbit can be stopped at a given point, the integration step reversed, and the calculations continued backward to the starting point, where any deviation of the matrix from a unit matrix reflects the error produced by the finite size of

*Work done under the auspices of the U. S. Atomic Energy Commission.
1. C. H. Moore, S. K. Howry, and H. S. Butler, TRANSPORT, a Computer Program for Designing Beam Transport Systems, Stanford University Linear Accelerator Report, 1964.
2. T. J. Devlin. OPTIK, an IBM 709 Computer Program for the Optics of High Energy Particle Beams, UCRL-9727, Sept. 1961.

the integration step and by the numerical procedures used. The program requires 47 200 octal words of memory for 10 000 decimal points in the field array.

EQUATIONS OF MOTION

The basic equations are integrated in rectangular coordinates, x, y. The median plane motion in a field B is described by

$$m \frac{d^2x}{dt^2} = \frac{e}{c} v \times B,$$

$$m \frac{d^2y}{dt^2} = -\frac{e}{c} v \times B.$$

The velocity v, trajectory length s, and time t are related by $\frac{ds}{dt} = v$; and momentum p, magnetic field B, and radius of curvature R are related by eBR = P. Then

$$\frac{d^2y}{dS^2} = -\frac{B_z(x, y)}{BR},$$

$$\frac{d^2x}{dS^2} = \frac{B_z(x, y)}{BR}$$

Reducing these second-order equations to first order by the substitution u = dx/ds and w = dy/ds gives

$$\frac{dx}{dS} = u,$$

$$\frac{dy}{dS} = w,$$

$$\frac{du}{dS} = \frac{B_z(x, y)}{BR},$$

$$\frac{dw}{dS} = -\frac{B_z(x, y)}{BR},$$

where the magnetic rigidity of the particle BR is related to momentum by $BR = 1.31324 \times 10^6 p$ in units of kilogauss-inches and MeV/c.

MATRIX EQUATIONS

TRAJ simultaneously integrates the equations of motion and the differential equations for the first-order ion optic matrix elements.[3] When the trajectory length, S, is taken as independent variable, the horizontal matrix compatible with a particle vector (x, θ, δp/p) can be written as

$$M_h = \begin{pmatrix} \cos k_x s & \frac{1}{k_x} \sin k_x s & \frac{1}{Rk_x^2}(1 - \cos k_x s) \\ -k_x \sin k_x s & \cos k_x s & \frac{1}{k_x R} \sin k_x s \\ 0 & 0 & 1 \end{pmatrix}$$

and the vertical matrix compatible with a particle vector (y, ϕ) as

$$M_V = \begin{pmatrix} \cos k_y s & \frac{1}{k_y} \sin k_y s \\ -k_y \sin k_y s & \cos k_y s \end{pmatrix},$$

where $k_x \equiv \sqrt{1-n}/R$, $k_y \equiv \sqrt{n}/R$, n is the field index - RdB/BdR, R the radius of curvature CP/eB, p the momentum, B the magnetic field, C the velocity of light, and e the unit of electric charge.

$$\frac{dM_h}{dS} = \begin{pmatrix} -k_x \sin k_x s & \cos k_x s & \frac{1}{Rk_x} \sin k_x s \\ -k_x^2 \cos k_x s & -k_x \sin k_x s & \frac{1}{R} \cos k_x s \\ 0 & 0 & 1 \end{pmatrix}$$

$$\frac{dM_v}{dS} = \begin{pmatrix} -k_y \sin k_y s & \cos k_y s \\ -k_y^2 \cos k_y s & -k_y \sin k_y s \end{pmatrix}$$

The matrix equations to be integrated become

$$\frac{dM_h(1,1)}{dS} = M_h(2,1),$$

$$\frac{dM_h(1,2)}{dS} = M_h(2,2),$$

$$\frac{dM_h(1,3)}{dS} = M_h(2,3),$$

$$\frac{dM_h(2,1)}{dS} = -k_x^2 M_h(1,1),$$

$$\frac{dM_h(2,2)}{dS} = -k_x^2 M_h(1,2),$$

$$\frac{dM_h(2,3)}{dS} = \frac{1}{R} - k_x^2(1,3),$$

3. This procedure is based on Program FOCUS, by Loren Meissner (unpublished).

$$\frac{dM_v(1,1)}{dS} = M_v(2,1),$$

$$\frac{dM_v(1,2)}{dS} = M_v(2,2),$$

$$\frac{dM_v(2,1)}{dS} = k_y^2\, M_v(1,1),$$

$$\frac{dM_v(2,2)}{dS} = k_y^2\, M_v(1,2)\ .$$

The integration is carried from the initial conditions

$$x = 0,$$
$$y = 0,$$
$$\frac{dx}{dS} = \cos\phi,$$
$$\frac{dy}{dS} = \sin\phi,$$

where ϕ is the angle between the particle direction and the tangent to the circle at the particle location, and

$$M_h(1,1) = 1,$$
$$M_h(1,2) = 0,$$
$$M_h(2,1) = 0,$$
$$M_h(2,2) = 1,$$
$$M_v(1,1) = 1,$$
$$M_v(1,2) = 0,$$
$$M_v(2,1) = 0,$$
$$M_v(2,2) = 1,$$

i. e., the matrices are started from unit matrices.

The coordinate system used by the ion optic transport codes by TRANSPORT and OPTIK are different, as shown in Figs. 4 and 5. Programs TRAJ and OPTIK use a right-handed system such that a positive field (flux lines upward) deflects protons to the right with the x axis to the left.

The coordinate system of TRANSPORT is such that a positive field (flux lines upward) deflects electrons to the left with the x axis to the right. This sign convention requires a sign reversal of the dispersive matrix elements when the TRAJ matrix is to be used with TRANSPORT. The natural system of units is used by OPTIK and TRAJ for particle vectors (inches, radians, percent), whereas TRANSPORT uses inches, milliradians, and percent. Therefore, a scaling matrix is employed by program TRAJ to convert its output into the appropriate coordinate and unit system. This scaling matrix is introduced by a 3. 7. 1. or 3. 7. 2. data card, and has the value

$$UU = \begin{pmatrix} 1. & 1. & 0. & 0. & 1. \\ 1. & 1. & 0. & 0. & 1. \\ 0. & 0. & 1. & 1. & 0. \\ 0. & 0. & 1. & 1. & 0. \\ 0. & 0. & 0. & 0. & 1. \end{pmatrix}$$

for OPTIK (3. 7. 2.) and the value

$$UU = \begin{pmatrix} 1. & .001 & 0. & 0. & -.01 \\ 1000. & 1. & 0. & 0. & -10. \\ 0. & 0. & 1. & 001. & 0. \\ 0. & 0. & 1000. & 1. & 0. \\ 0. & 0. & 0. & 0. & 1. \end{pmatrix}$$

for TRANSPORT (3. 7. 1.).

The TRANSPORT R(6, 6) matrix and TRAJ M(5, 5) matrix have the following correspondence:

$$R(\ ) = \begin{pmatrix} M_{11} & M_{12} & M_{13} & M_{14} & 0. & M_{15} \\ M_{21} & M_{22} & M_{23} & M_{24} & 0. & M_{25} \\ M_{31} & M_{32} & M_{33} & M_{34} & 0. & M_{35} \\ M_{41} & M_{42} & M_{43} & M_{44} & 0. & M_{45} \\ 0. & 0. & 0. & 0. & 1. & 0. \\ M_{51} & M_{52} & M_{53} & M_{54} & 0. & M_{55} \end{pmatrix}$$

The correspondence between the OPTIK T (6, 6) matrix and the TRAJ M (5, 5) matrix is

$$T(\ ) = \begin{pmatrix} M_{11} & M_{12} & M_{13} & M_{14} & M_{15} & 0 \\ M_{21} & M_{22} & M_{23} & M_{24} & M_{25} & 0 \\ M_{31} & M_{32} & M_{33} & M_{34} & M_{35} & 0 \\ M_{41} & M_{42} & M_{43} & M_{44} & M_{45} & 0 \\ M_{51} & M_{52} & M_{53} & M_{54} & M_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

The TRAJ matrix M( ) transforms a particle vector $(x, \theta, y, \phi, \delta p/p)$ in the forward direction,

$$V = M\, V_0.$$

The reverse matrix, M_r, transforms a particle vector, V to V_0,

$$V_0 = M_r V.$$

Obviously, $MM_r = 1$, therefore $M_r = M^{-1}$;

then the following relationship must exist between the forward and reverse matrix:

$$M=\begin{pmatrix} A & B & C \\ D & E & F \\ 0 & 0 & 1 \end{pmatrix} \qquad M^{-1}=\begin{pmatrix} E & -B & BF-EC \\ -D & A & DC-AF \\ 0 & 0 & 1 \end{pmatrix}.$$

The effect of these matrices on a particle vector is shown in Fig. 6. Both these matrices are printed as output under the headings of forward and reverse matrix.

PARAMETER INPUT

The various parameters of the calculation are read by subroutine READIN. The parameters are coded by a floating-point number described below. Once a parameter is changed, it so remains until changed again, except for the particle coordinates R, θ, ϕ, or X, Y, ϕ.

1. R. θ. ϕ. E. DS. SMAX. SOUT.

Particle input is in polar coordinates (R, θ), where R is in inches and θ is in degrees. The outward angular direction ϕ in degrees (shown in Fig. 7) is the angle between the particle direction and the tangent to a circle at the particle location. E is the particle energy in GeV, positive for a positive particle, negative for a negative particle. DS is the orbit integration step size in inches, and is taken negative if the orbit is to be calculated backward. SMAX is the maximum trajectory length (inches) with the printout of the ion optic matrix every SOUT (inches) along the trajectory. The FORMAT is (8F10.5).

Example: a 730-MeV proton starting tangentially at 78-inch radius at 172 deg azimuth can be specified by either of the following:

1. 78. 172. 0. .730 1. 100. 10.
1. 78. 172. 0. .730

2. X. Y. ϕ. E. DS. SMAX. SOUT.

Particle input in rectangular coordinates is in (8F10.0) format. The other parameters are the same as for polar coordinates. See Fig. 8.

Example: 2. 56.5 -56.5 0. .730 1. 100. 10.

3. PARAMETER VALUE

Parameter values used by TRAJ will be assumed standard unless changed by one or more of the following cards in (3F10.0) format.

3. 1. NC2. — — — — input of the order of Lagrangian interpolation of magnetic field values.
3. 2. EO. — — — — input of the rest mass of the particle in GeV.
3. 3. SMAX. — — — maximum trajectory length in inches.
3. 4. SOUT. — — — distance between matrix printouts in inches.
3. 5.
3. 6. SPRINT. — — SPRINT = 0 gives printout at each integration step, SPRINT $\neq$ 0 gives distance between orbit printouts if not for each integration step in steps of the integration size.
3. 7. MATRIX. — — = 1 matrix units for TRANSPORT. = 2 matrix units for OPTIK.
3. 8. PUNCH. — —
3. 9. PHIIN. — — — ϕ input unit degrees for PHIIN = 0, PR/P for PHIIN = 1.
3. 10. DS. — — — — integration step size in inches.

The standard values assumed by the program for the above parameters are NC2 = 7, EO = .938213 GeV, SMAX = 50 inches, SOUT = 50 inches, SPRINT = 0, MATRIX = 1., PUNCH = 0, PHIIN = 0, and DS = 1. inch.

4. XFIELD. BSCALE. PSCALE.

Magnetic field input specification. XFIELD selects the appropriate input subroutines. BSCALE scales the radial field data and PSCALE scales the perturbation data. Normally BSCALE = PSCALE = 1.

4. 1. 1. 1. Radial magnetic field of the 184-inch cyclotron.

4. 2. 1. 1. Radial field + perturbation over a given sector.

4. 3. 1. 1. Two-dimensional polar magnetic field over a given sector.

4. 4. 1. 1. Two-dimensional rectangular magnetic field.

The subroutines called by 4.3. and 4.4. data must be supplied by the user.

5. SELECT. VARIABLE.

The calculations can be interrupted by the use of this card to give the printout of the ion optic matrix at the specified value for either the particle radius, azimuth, or trajectory length. If the appropriate value does not lie on the integration step, the orbit is reversed one step and a linear interpolation is used to find the integration step required to produce the desired value of R, θ, or S. This step is then taken, the matrix printed, and the integration advanced to the original stopping point. The integration then continues as usual. The required data are in Format 3F10.4

5. 1. R. Prints matrix when radius = R.

5. 2. θ. Prints matrix when azimuth = θ.

5. 3. S. Prints matrix when trajectory length = S.

If the calculation is to be stopped at one of the above values so that other parameters can be changed, set STOP = SELECT by the following card:

5. 4. STOP. if STOP = 1. Calculations stop when radius is given on 5. 1. R,

if STOP = 2. Calculations stop when azimuth is value given on 5. 2. θ.

if STOP = 3. Calculations stop when trajectory length is as given on

5. 3. S.

6. N.

Read N. comment cards.

7. R1. R2. DR. AZIM. PHI1. PHI2. DPHI.

Track particles starting at azimuth AZIM with

radius R1, PHI = PHI1,
PHI1 + DPHI, ··· PHI2,

radius R1 + DR, PHI = PHI1,
PHI1 + DPHI, ··· PHI2,

⋮

radius R2, PHI = PHI1,
PHI1 + DPHI, ··· PHI2.

The total number of particles, N, tracked by this option is

$$N = \left(\frac{R2 - R1}{DR} + 1\right)\left(\frac{PHI2 - PHI1}{DPHI} + 1\right).$$

Radius is in inches, and PHI in units selected by the 3. 9. option.

The Format is (8F10.4).

8.

This card resumes the orbit and matrix calculation after it has been previously terminated without redefining the particle position. If one wishes to check the numerical accuracy produced by a given integration step size, he may calculate the trajectory out to some SMAX. and then reverse the calculation by reversing the sign of the integration step and calculate back to the original starting point by the following data:

1. R. θ. PHI. E. DS. SMAX. SOUT.

3. 10. -DS

8.

9.

This data card produces a page eject.

10.

This data card terminates the job.

Blank cards in the data deck are ignored except where they are required in the magnetic field input data sets.

MAGNETIC FIELD INPUT

One of four subroutines is used to read in the magnetic field. Subroutine B184 is used if XFIELD = 1. and reads the radially dependent, azimuthally independent field of the 184-inch cyclotron. Subroutines B184 and BP184 are called if XFIELD = 2. and store the radial field onto which are added field perturbations read from cards by BP184. These perturbations extend over the radial increment RMIN to RMAX and the azimuth sector defined by AMIN, AMAX. Subroutine B2DP is called if FIELD = 3. and reads a two-dimensional field in polar coordinates. Subroutine B2DP is called if XFIELD = 4. and reads a two-dimensional field in rectangular coordinates. Subroutines B2DP and B2DR are not supplied at present.

The sample data shown in Fig. 10 will track two protons of 730 MeV and three mesons in the forward direction, and then two protons in the reverse direction in the radial field of the 184-inch cyclotron. All data are in format (8F10.5) except comment card, whose format is (8A10).

SAMPLE DATA WITH FIELD PERTURBATIONS

The following example shows data for the radial magnetic field of the 184-inch cyclotron and the perturbations produced by the regenerator and magnetic channel (Fig. 9). These perturbations extend radially from 70 to 108 inches to 1-inch steps and azimuthally from 101 to 171 degrees in 1-degree steps. Within this boundary other perturbations may be added as shown. The format for the perturbation data is (I3, 2X15F5.0). The radius is the first number on the card (I3), and the data must be in radially increasing order. If more than one card is required per radius for the azimuthal field, the perturbations are in ascending azimuthal order at a given radius. A blank card signals the end of a perturbation set. Two blank cards in a row signal the end of all perturbation sets. The first card of a perturbation set gives the azimuth at which the data begins. In the example, shown in Fig. 11, a second set of perturbations begins at 142 degrees and covers the radial range from 98 to 103 inches extending to 156 degrees.

COMPUTER PROGRAM

A listing of the Fortran IV computer program is given in the Appendix.

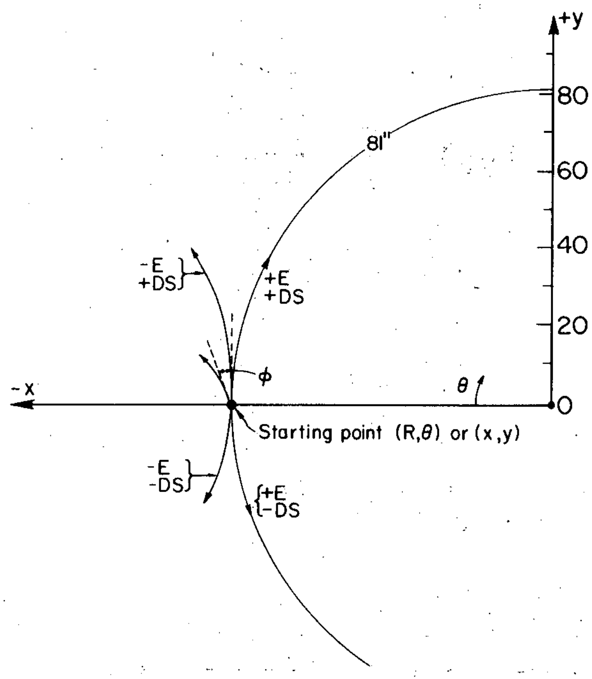

Fig. 1. Effect of sign of energy and integration step size.

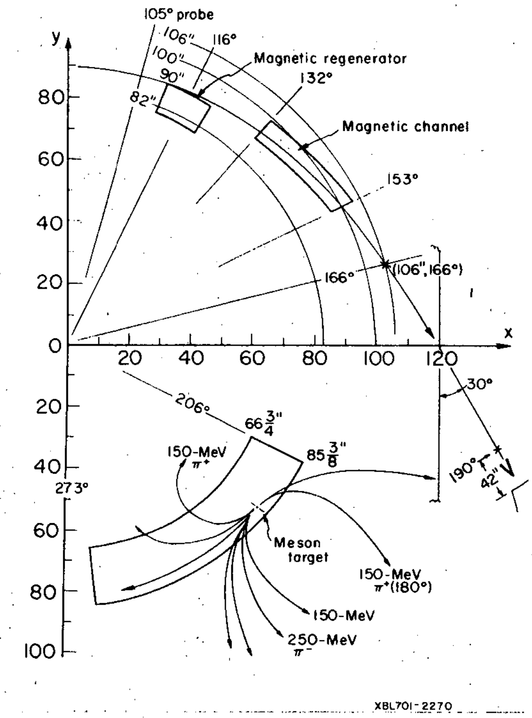

Fig. 3. Pion orbit tracking in the 184-inch cyclotron

```
INPUT DATA =      1.000000   90.096800  106.000000   3.112000    .700728   1.000000  200.000000   10.000000

P(GEV/C)= 1.3438318
DS(INCHES)=    1.000
BR(KG-IN)=  1.7648E+06
E(GEV)=  .7007280

 J  S(INCH)     X(INCH)  Y(INCH)  R(INCH)   AZ(DEG)     INDEX      B(GAUSS)        DPHI(DEG)
 1     0.       24.834   86.607   90.0969   106.0000    4.827E+00  19223.9          3.1120
 2    1.000     25.808   86.378   90.1512   106.6348    5.767E+00  19402.2          3.1199
 3    2.000     26.779   86.139   90.2056   107.2692    6.793E+00  19602.4          3.1211
 4    3.000     27.747   85.899   90.2600   107.9032    7.753E+00  19783.1          3.1158
 5    4.000     28.712   85.629   90.3143   108.5369    8.658E+00  19942.5          3.1059
 6    5.000     29.675   95.357   99.3683   109.1702    9.455E+00  20067.9          3.0885
 7    6.000     30.634   85.075   90.4220   109.8031    1.012E+01  20152.5          3.0685
 8    7.000     31.590   84.781   90.4754   110.4357    1.066E+01  20201.3          3.0460
 9    8.000     32.543   84.477   90.5283   111.0679    1.096E+01  20177.8          3.0220
10    9.000     33.492   84.162   90.5808   111.6997    1.093E+01  20057.0          3.0006
11   10.000     34.437   83.836   90.6330   112.3312    1.074E+01  19895.1          2.9844

          ------------------FORWARD MATRIX-----------------       ------------------REVERSE MATRIX-------------
          1.04254    .01017   0.         0.        -.00565        1.05660   -.01017   0.         0.        -.00572
          9.97562   1.05660   0.         0.       -1.14927       -9.97562   1.04254   0.         0.        1.14191
          0.        0.         .95195     .00981   0.             0.        0.         .93901   -.00981   0.
          0.        0.       -10.90265    .93801   0.             0.        0.       10.90265    .95195   0.
          RADIAL DETM=  1.000095   VERTICAL DETM=   .999897

 J  S(INCH)     X(INCH)  Y(INCH)  R(INCH)   AZ(DEG)     INDEX      B(GAUSS)        DPHI(DEG)
12   11.000     35.379   83.499   90.6850   112.9623    1.051E+01  19723.0          2.9722
13   12.000     36.316   83.152   90.7367   113.5931    1.022E+01  19540.0          2.9652
14   13.000     37.250   82.795   90.7885   114.2236    9.938E+00  19357.1          2.9643
15   14.000     38.180   82.427   90.8402   114.8536    9.672E+00  19180.4          2.9688
16   15.000     39.106   82.049   90.8921   115.4833    9.407E+00  19011.0          2.9785
17   16.000     40.028   81.662   90.9442   116.1127    9.278E+00  18876.6          2.9932
18   17.000     40.946   81.264   90.9965   116.7416    9.362E+00  18789.9          3.0107
19   18.000     41.859   80.857   91.0492   117.3702    9.495E+00  18713.1          3.0299
20   19.000     42.768   80.440   91.1023   117.9984    9.590E+00  18634.8          3.0521
21   20.000     43.672   80.013   91.1557   118.6263    9.653E+00  18558.4          3.0764

          ------------------FORWARD MATRIX-----------------       ------------------REVERSE MATRIX-------------
          1.20095    .02147   0.         0.        -.02317        1.21859   -.02147   0.         0.        -.02263
         21.58190   1.21859   0.         0.       -2.36894      -21.58190   1.20095   0.         0.        2.34486
          0.        0.         .78830     .01843   0.             0.        0.         .77397   -.01843   0.
          0.        0.       -21.15531    .77397   0.             0.        0.       21.15531    .78830   0.
          RADIAL DETM=  1.000018   VERTICAL DETM=   .999978

 J  S(INCH)     X(INCH)  Y(INCH)  R(INCH)   AZ(DEG)     INDEX      B(GAUSS)        DPHI(DEG)
22   21.000     44.572   79.577   91.2096   119.2537    9.658E+00  18479.5          3.1025
23   22.000     45.467   79.132   91.2640   119.8808    9.588E+00  18394.2          3.1309
24   23.000     46.358   78.677   91.3189   120.5074    9.436E+00  18299.5          3.1619
25   24.000     47.244   78.213   91.3743   121.1337    9.127E+00  18195.4          3.1958
26   25.000     48.125   77.740   91.4304   121.7596    8.644E+00  18094.3          3.2327
27   26.000     49.001   77.258   91.4871   122.3850    8.141E+00  17961.1          3.2729
28   27.000     49.872   76.767   91.5446   123.0101    7.673E+00  17820.2          3.3171
29   28.000     50.739   76.267   91.6029   123.6347    7.226E+00  17659.4          3.3657
30   29.000     51.600   75.759   91.6620   124.2589    6.817E+00  17473.3          3.4195
31   30.000     52.456   75.242   91.7222   124.8826    6.446E+00  17260.5          3.4793

          ------------------FORWARD MATRIX-----------------       ------------------REVERSE MATRIX-------------
          1.47529    .03482   0.         0.        -.05347        1.44813   -.03482   0.         0.        -.05111
```

Fig. 2. Example of program output.

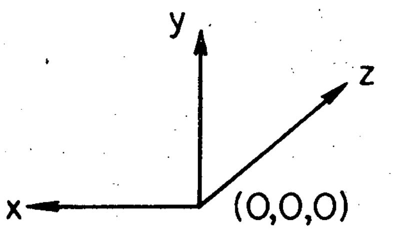

Fig. 4. TRAJ and OPTIK coordinate system.

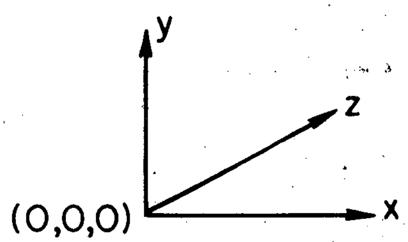

Fig. 5. TRANSPORT coordinate system.

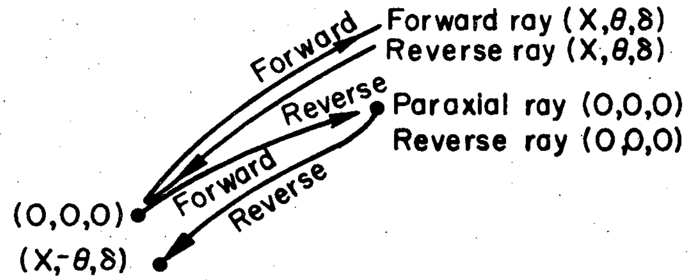

Fig. 6. Beginning and end points for particle vectors tracked by the forward and reverse matrices.

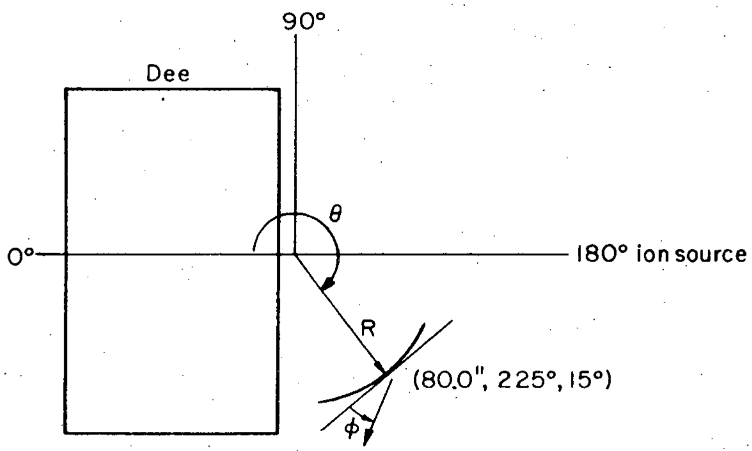

Fig. 7. Polar geometry of 184-inch cyclotron; ϕ is taken positive for positive radial momentum (outward).

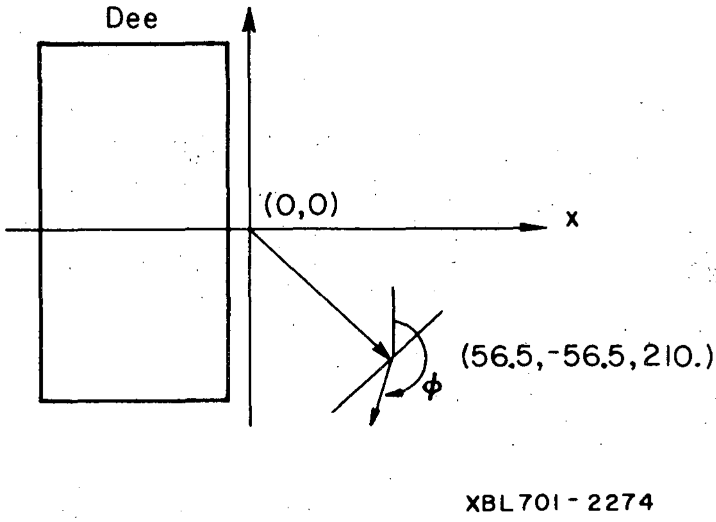

Fig. 8. Rectangular geometry for 184-inch cyclotron for same input conditions shown above; $\phi_{rect} = \theta_{polar} - \phi_{polar}$.

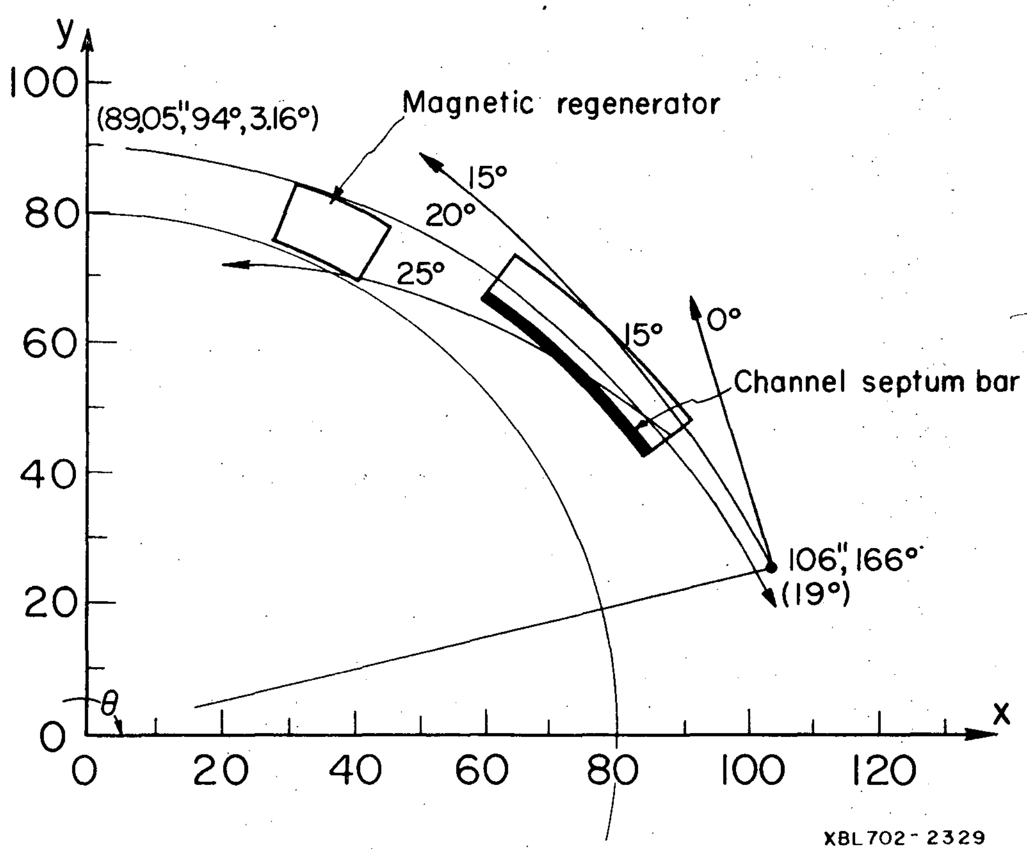

Fig. 9. Backward tracking into magnetic channel.

```
4.        1.        1.
RADIAL FIELD
1.        108.      1.
     23347     23327     23306     23284     23261     23238     23217     23198
     23181     23164     23147     23130     23112     23094     23075     23056
     23037     23020     23004     22990     22977     22964     22952     22940
     22928     22915     22902     22888     22874     22860     22845     22830
     22816     22802     22789     22776     22764     22752     22741     22730
     22720     22709     22698     22687     22676     22665     22654     22642
     22630     22618     22606     22594     22583     22572     22561     22551
     22541     22531     22520     22510     22503     22498     22493     22487
     22479     22470     22459     22447     22435     22423     22412     22403
     22395     22387     22379     22371     22362     22354     22346     22338
     22326     22298     22236     22116     21916     21618     21209     20685
     20043     19265     18347     17327     16256     15180     14136     13133
     12169     11250     10380      9560      8792      8070      7389      6745
      6135      5560      5022      4517
BLANK CARD
1.        81.       92.       3.        .730      1.        100.      10.
2.        81.       3.        3.
3.        2.        .139579
1.        77.       220.      0.        -.12
1.        78.       220.      0.        -.18
1.        79.       220.      0.        -.20
3.        2.        .938213
2.        0.        90.       0.        .7        -1.
2.        0.        90.       2.
BLANK CARD
```

Fig. 10. Example of radial magnetic field input data.

```
    4.        2.        1.        1.
RADIAL MAGNETIC FIELD AND REGENERATOR AND CHANNEL PURTURBATIONS OF 184
  1.        108.      1.        1.
     23347     23327     23306     23284     23261     23238     23217     23198
     23181     23164     23147     23130     23112     23094     23075     23056
     23037     23020     23004     22990     22977     22964     22952     22940
     22928     22915     22902     22888     22874     22860     22845     22830
     22816     22802     22789     22776     22764     22752     22741     22730
     22720     22709     22698     22687     22676     22665     22654     22642
     22630     22618     22606     22594     22583     22572     22561     22551
     22541     22531     22520     22510     22503     22498     22493     22487
     22479     22470     22459     22447     22435     22423     22412     22403
     22395     22387     22379     22371     22362     22354     22346     22338
     22326     22298     22236     22116     21916     21618     21209     20685
     20043     19265     18347     17327     16256     15180     14136     13133
     12169     11250     10380      9560      8792      8070      7389      6745
      6135      5560      5022      4517
BLANK CARD
70.       108.      1.        101.      171.      1.
101
 71   -32  -36  -38  -36  -30  -21   -5   12   28   42   50   48   41   29   14
 71    -2  -14  -25  -36  -48  -60  -77  -92 -104 -110 -110  -95  -77  -57  -39
 71   -27  -31  -41  -52  -61  -65  -52  -33  -11   11   29   34   34   32   29
 71    28   37   49   62   76   87   91   92   91   88   85   84   84   86   89
 71    92   98  102  101   94   79   49   16  -18  -46  -66
 72    -3   -8  -12  -14  -13   -8    6   21   37   50   58   54   45   32   16
 72    -1  -12  -23  -33  -44  -56  -75  -92 -106 -114 -115  -99  -78  -55  -36
 72   -23  -30  -42  -57  -69  -76  -63  -44  -20    3   24   30   31   30   28
 72    28   38   51   65   78   89   92   91   88   84   81   81   82   86   91
 72    97  106  112  113  107   92   61   25  -11  -43  -65
 73    25   18    9    1   -4   -4    8   24   41   56   66   63   54   41   24
 73     7   -4  -14  -25  -37  -50  -71  -92 -108 -118 -120 -102  -79  -54  -32
 73   -17  -24  -37  -53  -68  -78  -68  -50  -29   -6   14   20   22   22   21
 73    22   33   47   62   76   86   87   85   80   75   71   72   75   82   90
 73    99  111  119  122  117  102   69   31   -7  -41  -65
107    -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0
107    -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0
107    -0   -0   -0   -0   -0   -0    2    4    4    3   -0  -10  -18  -21  -16
107    -0   36   79  124  166  200  213  214  202  180  150  117   82   50   22
107    -0  -10  -14  -12   -6   -0    2    3    3    2   -0
108    -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0
108    -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0    0    0
108     0    0    0    0    0    0    0    0   -0   -0   -0   -0   -0   -0   -0
108    -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0
108    -0   -0   -0   -0   -0   -0   -0   -0   -0   -0   -0
BLANK CARD
142
 98    25   25   25   25   25   25   25   25   25   25   25   25   25   25   25
 99   100  100  100  100  100  100  100  100  100  100  100  100  100  100  100
100   200  200  200  200  200  200  200  200  200  200  200  200  200  200  200
101   375  375  375  375  375  375  375  375  375  375  375  375  375  375  375
102   200  200  200  200  200  200  200  200  200  200  200  200  200  200  200
103   100  100  100  100  100  100  100  100  100  100  100  100  100  100  100
BLANK CARD
BLANK CARD
1.        89.05     94.       3.14      .730      1.        100.      10.
BLANK CARD
```

Fig. 11 Example of radial and azimuthal perturbation magnetic field data input.

```
$IBFTC TRAJ
      PROGRAM TRAJ(INPUT,OUTPUT,TAPE2)
C
C
C
C
C
C -----------------------------------------------------------------------
C
C   PROGRAM TRAJ
C         PROGRAM TO CALCULATE ORBITS IN GIVEN MAGNETIC FIELD IN POLAR
C         OR RECTANGULAR COORDINATES SIMULTANEOUSLY INTEGRATING THE
C         DIFFERENTIAL EQUATIONS FOR THE FIRST ORDER ION OPTIC MATRIX
C         ELEMENTS. THE PROGRAM IS BASED ON FOCUS BY LOREN MEISNER.
C
C                          A. C. PAUL
C                          SEPT. 30, 1969
C
C      INPUT DATA
C        1. R. THETA. PHI. E.DS. SMAX. SOUT.     PARTICLE INPUT IN POLOR
C        2. X. Y. PHI. E.  DS.  SMAX.  SOUT.     PARTICLE INPUT IN
C                                                RECTANGULAR COORDINATES
C        3. PARM. VALUE.
C                               PARM=1  VALUE=XNC2  ORDER OF INTERPOLATION
C                               PARM=2  VALUE=E0    REST ENERGY OF PARTICLE
C                               PARM=3  VALUE=SMAX  MAX TRAJECTORY LENGTH
C                               PARM=4  VALUE=SOUT  MATRIX PRINT STEP SIZE
C                               PARM=5  VALUE=JMAX  MAX NUMBER OF INTEGRATN
C                               PARM=6  VALUE=SPRINT  PRINT STEP SIZE
C                               PARM=7  VLAUE=MATRIX  1 FOR TRANSPORT
C                                                     2 FOR OPTIK
C                               PARM=8  VALUE=PUNCH=1  PUNCH MATRIX
C                               PARM=9  VALUE =PHI-IN  0 FOR DEGREES
C                                                      1 FOR PR/P
C                               PARM=10 VALUE=DS  INTEGRATION STEP SIZE
C        4. FIELD. BSCALE. PSCALE.
C                               FIELD=1  RADIAL FIELD
C                               FIELD=2  RADIAL FIELD PLUS PURTURBATIONS
C                               FIELD=3  2 DIMENSIONAL POLAR FIELD
C                               FIELD=4  2-DIMENSIONAL RECTANGULAR FIELD
C        5. SELEC. VALUE.
C                               SELEC=1   VALUE=R  RADIUS FOR MATRIX OUTPUT
C                               SELEC=2   VALUE=THETA  FOR MATRIX OUTPUT
C                               SELEC=3   VALUE=TRAJECTORY LENGTH FOR MATRIX
C                                                                    OUTPUT
C                               SELEC=4    VALUE=1.  STOP AT DESIRED R VALUE
C                                          VALUE=2.  STOP AT DESIRED T VALUE
C                                          VALUE=3.  STOP AT DESIRED S VALUE
C        6. N.                  READ N TITLE CARDS
C        7. R1. R2. DR. AZIM. PHI1. PHI2. DPHI.
C                               START PARTICLES AT AZIMUTH=AZIM
C                               WITH RADIUS=R1,R1+DR,..R2 IN STEPS OF DR
C                               EACH WITH PHI VALUE GOING FROM PHI1 TO
C                               PHI2 IN STEPS OF DPHI
C        8.                     CONTINUE ORBIT AND MATRIX CALCULATION FROM
C                               POINT OF TERMINATION OF LAST INTEGRATION
C                               I.E. NO REDEFINING STARTING POINT OR NO
C                               USE OF 1. DATA CARD TO START ORBITS
C        9.                     PAGE EJECT
C       10.                     STOP
C
C

C         BLANK CARDS IN THE DATA SET ARE IGNORED EXCEPT WHERE
C         REQUIRED IN THE MAGNETIC FIELD DATA SETS WHERE THEY ARE USED
C         AS DATA DELIMITERS
C
C
C      TRAJECTORY MATRIX CONVENTION
C                   POSITIVE FIELD BENDS ELECTRONS TO THE LEFT WITH THE
C                   +X AXIS ON THE LEFT
C                   UNITS OF MATRIX CCMPATABLE WITH PARTICLE VECTOR
C                   (X,THETA,DP/P) IN UNITS OF INCHES,RADIANS,FRACTION
C                   USE A 3.  7.  2.
C      TRANSPORT MATRIX CONVENTION
C                   POSITIVE FIELD BENDS ELECTRONS TO THE LEFT WITH THE
C                   +X AXIS ON THE RIGHT
C                   UNITS OF MATRIX COMPATABLE WITH THE PARTICLE VECTOR
C                   (X,THETA,DP/P) IN UNITS OF INCHES,MILLIRADIANS,PERCENT
C                   USE A 3.  7.  1.
C
C
C      DATA FORMAT(8F10.0) EXCEPT WHERE NOTED FOR MAGNETIC FIELD INPUT
C      TITLE CARD FORMAT (8A10)
C   SAMPLE DATA
C         6.  1.
C         TRACK 730 MEV PROTONS
C         4.  1.  1.  1.
C         RADIAL FIELD FOR 184 INCH CYCLOTRON
C         61.  108.  1.  1.
C         22503. 22458. 22493. 22487. 22479. 22470. 22459. 22447.
C         22435. 22423. 22417. 22403. 22395. 22387. 22379. 22371.
C         22362. 22354. 22346. 22338. 22326. 22278. 22236. 22116.
C         21916. 21613. 21209. 20685. 20043. 19265. 18347. 17327.
C         16256. 15180. 14136. 13133. 12165. 11250. 10380.  9560.
C          8792.  8070.  7389.  6745.  6135.  5560.  5022.  4517.
C         BLANK CARD
C         5.  1.  92.
C         5.  2.  164.
C         5.  3.  12.5
C         1.  91.  153.  10.  .730  .5  30.  30.
C         7.  91.  915.  .5  153.  5.  15.  5.
C         10.
C
C
C
C      FOLLOWING A 4. 1. 1. 1. CARD
C                   TITLE CARD
C                   RMIN,RMAX,DR,BSCALE
C                   ..........
C                   ..........
C                   RADIAL FIELD IN ASSENDING ORDER OF RADIUS
C                   EXTENDING FROM RMIN TO RMAX IN STEPS OF DR
C                   FORMAT(8F10.0)
C                   .......
C                   BLANK CARD
C      FOLLOWING A 4. 2. 1. 1. CARD
C                   TITLE CARD
C                   RMIN,RMAX,DR,BSCALE
C                   RADIAL FIELD AS ABOVE
C                   BLANK CARD
C                   RMIN,RMAX,DR,BSCALE
C                   ......
C                   ......
C                   PURTURBATIONSIN ASSENDING ORDER OF AZIMUTH FOR EACH
```

```
C                   RADIUS.  R,F(1),B(2),.......B(15)
C                   FORMAT(I3,2X15F5.0)
C                   ......
C                   ......
C                   BLANK CARD
C                   BLANK CARD
C                   BLANK CARD
C
C
C -----------------------------------------------------------------------
C
C
C
      DIMENSION TITLE(12)
       DIMENSION U(14),V(14),DV(4,14)
      COMMON IFLAG,S,DS,U,V,DV,JMAX,KILL,BTEL,GRAD,PHI,
     2    XMAX,XMIN,YMAX,YMIN,ZMAX,ZMIN,BX,BY,PZ,XIN,YIN,ZIN,
     2    XO,YO,ZO,BRHO,BRHOI,THETA,
     3  BOLD(2)
      COMMON/BCOM/B(10000)
      COMMON/COM1/ IFIELD,NC1,NC2,NR,NA,NB,TABR(200),TABA(200),TABB(200)
      COMMON/COM2/TABR1(200),NB1,RLIM1,RLIM2,RLIM3,RLIM4
      COMMON/COM3/P,SMAX,SOUT,SPRINT,DSB,MATRIX,IPUNCH
      COMMON/COM4/BSCALE,PSCALE,TABO(200)
      COMMON/COM5/AZI,R
      COMMON/COM6/RMATX,TMATX,SMATX,DMATX,MPURCE
      COMMON/COM7/RP1,RP2,DRP,AZIPO,THE1,THE2,DTHE
      COMMON/AJUNE/ R1,R2,DR
      COMMON/CARKI/ NECNN
 2000 FORMAT(8F10.0)
 2010 FORMAT(8F10.0)
 2020 FORMAT(12A6)
 3000 FORMAT(1H1)
 3010 FORMAT(1H0,*R1,R2,DR,BZS=*3F10.3,F15.6)
 3020 FORMAT(10X10F10.2)
 3030 FORMAT(10X7A10)
 3040 FORMAT(1H0,15HPARTICLE NUMBER,I4,1X90(1H-),16H PARTICLE NUMBER,I4)
C
C
      DIMENSION TEXT(1000)
      EQUIVALENCE(TEXT,U)
      DATA(TEXT(J),J=   1,  40)/
     *  10H----------, 10H----------, 10H----------, 10H----------,
     *  10H----------, 10H----------, 10H----------, 10H          ,
     *  10H          , 10H          , 10H          , 10H          ,
     *  10H          , 10H          , 10H PROGRAM T, 10HRAJ       ,
     *  10H          , 10H          , 10H          , 10H          ,
     *  10H          , 10H       PRO, 10HGRAM TO CA, 10HLCULATE OR,
     *  10HBITS IN GI, 10HVEN MAGNET, 10HIC FIELD I, 10HN POLAR   ,
     *  10H       OR , 10HRECTANGULA, 10HR COORDINA, 10HTES SIMULT,
     *  10HANEOUSLY I, 10HNTEGRATING, 10H THE      , 10H       DIF,
     *  10HFERENTIAL , 10HEQUATIONS , 10HFOR THE FI, 10HRST ORDER
     *    /
      DATA(TEXT(J),J=  41,  80)/
     *  10HION OPTIC , 10HMATRIX    , 10H       ELE, 10HMENTS.  TH,
     *  10HE PROGRAM , 10HIS BASED O, 10HN FOCUS BY, 10H LOREN MEI,
     *  10HSNER.     , 10H          , 10H          , 10H          ,
     *  10H          , 10H          , 10H          , 10H          ,
     *  10H          , 10H          , 10H   A. C. P, 10HAUL       ,
     *  10H          , 10H          , 10H          , 10H          ,
     *  10H          , 10H   SEPT. 3, 10H0, 1969   , 10H          ,
     *  10H          , 10H          , 10H          , 10H          ,

     *  10H          , 10H          , 10H          , 10H          ,
     *  10H          , 10H    INPUT , 10HDATA      , 10H
     *    /
      DATA(TEXT(J),J=  81, 120)/
     *  10H          , 10H          , 10H          , 10H          ,
     *  10H       1. , 10HR. THETA. , 10HPHI. E.DS., 10H SMAX. SOU,
     *  10HT.     PAR, 10HTICLE INPU, 10HT IN POLOR, 10H        2. ,
     *  10HX. Y. PHI., 10H E.  DS.  , 10HSMAX.  SOU, 10HT.     PAR,
     *  10HTICLE INPU, 10HT IN      , 10H          , 10H          ,
     *  10H          , 10H          , 10H       REC, 10HTANGULAR C,
     *  10HOORDINATES, 10H       3. , 10HPARM. VALU, 10HE.        ,
     *  10H          , 10H          , 10H          , 10H          ,
     *  10H          , 10H          , 10H       PAR, 10HM=1  VALUE,
     *  10H=XNC2  ORD, 10HER OF INTO, 10HRPOLATION , 10H
     *    /
      DATA(TEXT(J),J= 121, 160)/
     *  10H          , 10H       PAR, 10HM=2  VALUE, 10H=E0    RES,
     *  10HT ENERGY O, 10HF PARTICLE, 10H          , 10H          ,
     *  10H       PAR, 10HM=3  VALUE, 10H=SMAX  MAX, 10H TRAJECTOR,
     *  10HY LENGTH  , 10H          , 10H          , 10H       PAR,
     *  10HM=4  VALUE, 10H=SOUT  MAT, 10HRIX PRINT , 10HSTEP SIZE ,
     *  10H          , 10H          , 10H       PAR, 10HM=5  VALUE,
     *  10H=JMAX  MAX, 10H NUMBER OF, 10H INTEGRATN, 10H          ,
     *  10H          , 10H       PAR, 10HM=6  VALUE, 10H=SPRINT  P,
     *  10HRINT STEP , 10HSIZE      , 10H          , 10H          ,
     *  10H       PAR, 10HM=7  VLAUE, 10H=MATRIX  1, 10H FOR TRANS
     *    /
      DATA(TEXT(J),J= 161, 200)/
     *  10HPORT      , 10H          , 10H          , 10H          ,
     *  10H          , 10H         2, 10H FOR OPTIK, 10H          ,
     *  10H          , 10H          , 10H       PAR, 10HM=8  VALUE,
     *  10H=PUNCH=1  , 10HPUNCH MATR, 10HIX        , 10H          ,
     *  10H          , 10H       PAR, 10HM=9  VALUE, 10H =PHI-IN  ,
     *  10H0 FOR DEGR, 10HEES       , 10H          , 10H          ,
     *  10H          , 10H          , 10H          , 10H1 FOR PR/P,
     *  10H          , 10H          , 10H          , 10H       PAR,
     *  10HM=10 VALUE, 10H=DS  INTEG, 10HRATION STE, 10HP SIZE    ,
     *  10H       4. , 10HFIELD. BSC, 10HALE. PSCAL, 10HE.
     *    /
      DATA(TEXT(J),J= 201, 240)/
     *  10H          , 10H          , 10H          , 10H          ,
     *  10H          , 10H       FIE, 10HLD=1  RADI, 10HAL FIELD  ,
     *  10H          , 10H          , 10H          , 10H          ,
     *  10H       FIE, 10HLD=2  RADI, 10HAL FIELD P, 10HLUS PURTUR,
     *  10HBATIONS   , 10H          , 10H          , 10H       FIE,
     *  10HLD=3  2 DI, 10HMENSIONAL , 10HPOLAR FIEL, 10HD         ,
     *  10H          , 10H          , 10H       FIE, 10HLD=4  2-DI,
     *  10HMENSIONAL , 10HRECTANGULA, 10HR FIELD   , 10H       5. ,
     *  10HSELEC. VAL, 10HUE.       , 10H          , 10H          ,
     *  10H          , 10H          , 10H          , 10H
     *    /
      DATA(TEXT(J),J= 241, 280)/
     *  10H       SEL, 10HEC=1  VALU, 10HE=R  RADIU, 10HS FOR MATR,
     *  10HIX OUTPUT , 10H          , 10H          , 10H       SEL,
     *  10HEC=2  VALU, 10HE=THETA  F, 10HOR MATRIX , 10HOUTPUT    ,
     *  10H          , 10H          , 10H       SEL, 10HEC=3  VALU,
     *  10HE=TRAJECTO, 10HRY LENGTH , 10HFOR MATRIX, 10H          ,
     *  10H          , 10H          , 10H          , 10H          ,
     *  10H          , 10H    OUTPUT, 10H          , 10H          ,
     *  10H       SEL, 10HEC=4    VAL, 10HUE=1.  STO, 10HP AT DESIR,
     *  10HED R VALUE, 10H          , 10H          , 10H          ,
     *  10H       VAL, 10HUE=2.  STO, 10HP AT DESIR, 10HED T VALUE
```

```
*    /
 DATA(TEXT(J),J= 281, 320)/
*  10H          , 10H          , 10H          , 10H       VAL,
*  10HH=1.   STO, 10HP AT DESIR, 10HED S VALUE, 10H        6. ,
*  10HN.        , 10H       BLA, 10HD N TITLE , 10HCARDS      ,
*  10H          , 10H          , 10H        7. , 10HR1. R2. DR,
*  10H. AZIM. PH, 10HI1. PHI2. , 10HDPHI.     , 10H          ,
*  10H          , 10H          , 10H          , 10H       STA,
*  10HRT PARTICL, 10HES AT AZIM, 10HUTH=AZIM  , 10H          ,
*  10H          , 10H          , 10H       WIT, 10HH RADIUS=R,
*  10H1,R1+DR..., 10HR2 IN STEP, 10HS OF DR   , 10H          ,
*  10H          , 10H       EAC, 10HH WITH PHI, 10H VALUE GOI
*    /
 DATA(TEXT(J),J= 321, 360)/
*  10HNG FROM PH, 10HI1 TO     , 10H          , 10H          ,
*  10H       PHI, 10H2 IN STEPS, 10H OF DPHI  , 10H          ,
*  10H          , 10H        8. , 10H          , 10H       CON,
*  10HTINUE ORBI, 10HT AND MATR, 10HIX CALCULA, 10HTION FROM ,
*  10H          , 10H          , 10H       POI, 10HNT OF TERM,
*  10HINATION OF, 10H LAST INTE, 10HGRATION   , 10H          ,
*  10H          , 10H       I.E, 10H. NO REDEF, 10HINING STAR,
*  10HTING POINT, 10H OR NO    , 10H          , 10H          ,
*  10H       USE, 10H OF I. DAT, 10HA CARD TO , 10HSTART ORBI,
*  10HTS        , 10H        9. , 10H          , 10H       PAG
*    /
 DATA(TEXT(J),J= 361, 400)/
*  10HE EJECT   , 10H          , 10H          , 10H          ,
*  10H       10. , 10H          , 10H       STO, 10HP          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H       BLA, 10HNK CARDS I, 10HN THE DATA,
*  10H SET ARE I, 10HGNORED EXC, 10HEPT WHERE , 10H          ,
*  10H       REQ, 10HUIRED IN T, 10HHE MAGNETI, 10HC FIELD DA,
*  10HTA SETS WH, 10HERE THEY A, 10HRE USED   , 10H        AS
*    /
 DATA(TEXT(J),J= 401, 440)/
*  10HDATA DELIM, 10HITERS     , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H    TRAJEC, 10HTORY MATRI, 10HX CONVENTI, 10HON        ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H       POS, 10HITIVE FIEL, 10HD BENDS EL, 10HECTRONS TO,
*  10H THE LEFT , 10HWITH THE  , 10H          , 10H        +X ,
*  10HAXIS ON TH, 10HE LEFT    , 10H          , 10H
*    /
 DATA(TEXT(J),J= 441, 480)/
*  10H          , 10H          , 10H       UNI, 10HTS OF MATR,
*  10HIX COMPATA, 10HBLE WITH P, 10HARTICLE VE, 10HCTOR      ,
*  10H          , 10H       (X,, 10HTHETA,DP/P, 10H) IN UNITS,
*  10H OF INCHES, 10H,RADIANS,F, 10HRACTION   , 10H          ,
*  10H       USE, 10H A 3.  7. , 10H 2.       , 10H          ,
*  10H          , 10H          , 10H    TRANSP, 10HORT MATRIX,
*  10H CONVENTIO, 10HN         , 10H          , 10H          ,
*  10H          , 10H          , 10H       POS, 10HITIVE FIEL,
*  10HD BENDS EL, 10HECTRONS TO, 10H THE LEFT , 10HWITH THE  ,
*  10H          , 10H        +X , 10HAXIS ON TH, 10HE RIGHT
*    /
 DATA(TEXT(J),J= 481, 520)/
*  10H          , 10H          , 10H          , 10H          ,
*  10H       UNI, 10HTS OF MATR, 10HIX COMPATA, 10HBLE WITH T,
*  10HHE PARTICL, 10HE VECTOR  , 10H          , 10H       (X,,
*  10HTHETA,DP/P, 10H) IN UNITS, 10H OF INCHES, 10H,MILLIRADI,
*  10HANS,PERCEN, 10H          , 10H       USE, 10H A 3.  7. ,
*  10H 1.       , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H    DATA F, 10HORMAT(8F10
*    /
 DATA(TEXT(J),J= 521, 560)/
*  10H.0) EXCEPT, 10H WHERE NOT, 10HED FOR MAG, 10HNETIC FIEL,
*  10HD INPUT   , 10H     TITLE , 10HCARD FORMA, 10HT (8A10)  ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H SAMPLE DA, 10HTA        , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H        6. ,
*  10H 1.       , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H       TRA, 10HCK 730 MEV,
*  10H PROTONS  , 10H          , 10H          , 10H          ,
*  10H          , 10H       4. , 10H 1.  1.  1, 10H.         ,
*  10H          , 10H          , 10H          , 10H
*    /
 DATA(TEXT(J),J= 561, 600)/
*  10H       RAD, 10HIAL FIELD , 10HFOR 184 IN, 10HCH CYCLOTR,
*  10HON        , 10H          , 10H          , 10H       61.,
*  10H  108.  1., 10H  1.      , 10H          , 10H          ,
*  10H          , 10H          , 10H       225, 10H03. 22498.,
*  10H 22493. 22, 10H487. 22479, 10H. 22470. 2, 10H2459. 2244,
*  10H7.        , 10H       224, 10H35. 22423., 10H 22412. 22,
*  10H403. 22395, 10H. 22387. 2, 10H2379. 2237, 10H1.        ,
*  10H       223, 10H62. 22354., 10H 22346. 22, 10H338. 22326,
*  10H. 22298. 2, 10H2236. 2211, 10H6.        , 10H       219,
*  10H16. 21618., 10H 21205. 20, 10H685. 20043, 10H. 19265. 1
*    /
 DATA(TEXT(J),J= 601, 640)/
*  10H8347. 1737, 10H7.        , 10H       162, 10H56. 15180.,
*  10H 14136. 13, 10H133. 12169, 10H. 11250. 1, 10H0380. 956,
*  10H0.        , 10H        87, 10H92. 8070., 10H 7389.  6,
*  10H745. 6135., 10H.  5550.  , 10H5022.  451, 10H7.        ,
*  10H       BLA, 10HNK CARD   , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H        5. ,
*  10H 1.  52.  , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H        5. , 10H 2.  168. ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H        5. , 10H 3.  12.5 , 10H
*    /
 DATA(TEXT(J),J= 641, 680)/
*  10H          , 10H          , 10H          , 10H          ,
*  10H        1. , 10H 91.  153., 10H  10.  .73, 10H0  .5  30.,
*  10H  30.     , 10H          , 10H          , 10H        7. ,
*  10H 91.  91., 10H  .5  153., 10H  5.  15. , 10H 5.       ,
*  10H          , 10H          , 10H       10., 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H
*    /
 DATA(TEXT(J),J= 681, 720)/
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H    FOLLOW, 10HING A 4. 1,
*  10H. 1. 1. CA, 10HRD        , 10H          , 10H          ,
*  10H          , 10H          , 10H       TIT, 10HLE CARD    ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H       RMI, 10HN,RMAX,DR,, 10HBSCALE     ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H       ...., 10H.......   , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H       ....,
*  10H.......   , 10H          , 10H          , 10H
*    /
 DATA(TEXT(J),J= 721, 760)/
*  10H          , 10H          , 10H       RAD, 10HIAL FIELD ,
*  10HIN ASSENDI, 10HNG ORDER O, 10HF RADIUS  , 10H          ,
*  10H          , 10H       EXT, 10HENDING FRO, 10HM RMIN TO ,
*  10HRMAX IN ST, 10HEPS OF DR , 10H          , 10H          ,
*  10H       FOR, 10HMAT(8F10.0, 10H)         , 10H          ,
*  10H          , 10H          , 10H          , 10H       ....,
*  10H.....     , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H       BLA, 10HNK CARD    ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H    FOLLOW, 10HING A 4. 2, 10H. 1. 1. CA, 10HRD
*    /
 DATA(TEXT(J),J= 761, 800)/
*  10H          , 10H          , 10H          , 10H          ,
*  10H       TIT, 10HLE CARD   , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H       RMI,
*  10HN,RMAX,DR,, 10HBSCALE    , 10H          , 10H          ,
*  10H          , 10H          , 10H       RAD, 10HIAL FIELD ,
*  10HAS ABOVE  , 10H          , 10H          , 10H          ,
*  10H          , 10H       BLA, 10HNK CARD   , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H       RMI, 10HN,RMAX,DR,, 10HBSCALE    , 10H          ,
*  10H          , 10H          , 10H          , 10H       ...
*    /
 DATA(TEXT(J),J= 801, 840)/
*  10H...       , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H       ...., 10H...       ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H       PER, 10HTURBATIONS, 10HIN ASSENDI,
*  10HNG ORDER O, 10HF AZIMUTH , 10HFOR EACH  , 10H          ,
*  10H       RAD, 10HIUS.  R,B(, 10H1),B(2),..., 10H....B(15) ,
*  10H          , 10H          , 10H          , 10H       FOR,
*  10HMAT(I3,2X), 10H15F5.0)   , 10H          , 10H          ,
*  10H          , 10H          , 10H       ...., 10H...       ,
*  10H          , 10H          , 10H          , 10H
*    /
 DATA(TEXT(J),J= 841, 880)/
*  10H          , 10H       ...., 10H...       , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H       BLA, 10HNK CARD   , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H       BLA,
*  10HNK CARD   , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H       BLA, 10HNK CARD    ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H
*    /
 DATA(TEXT(J),J= 881, 900)/
*  10H          , 10H          , 10H----------, 10H----------,
*  10H----------, 10H----------, 10H----------, 10H----------,
*  10H----------, 10H          , 10H          , 10H          ,
*  10H          , 10H          , 10H          , 10H          ,
*  10H          , 10H  3.  -.4, 10H  .6  0.  , 10H80.5  30.5
*    /
      PRINT 3000
      NTEXT=900
      PRINT 3030,(TEXT(J),J=1,NTEXT)
C
      CALL INITAL
      GO TO 200
C     RADIAL FIELD WITH NO AZIMUTHAL VARIATIONS
  100 CONTINUE
      READ 2020,TITLE
      PRINT 2020,TITLE
      READ 2010,R1,R2,DR,BZS
      PRINT 3010,R1,R2,DR,BZS
      NB=IFIX((R2-R1)/DR)+1
      NB1=NB
      READ 2010,(TABB(J),J=1,NB)
      PRINT 3020,(TABB(J),J=1,NB)
      READ 2010,BJUNK
C
C
      CALL B184
      IF(IFIELD.NE.2) GO TO 200
C     RADIAL FIELD PLUS POLAR PERTURBATIONS
      CALL BP184
      GO TO 200
C
C
C     2 DIMENSIONAL FIELD INPUT,  POLAR COORDINATES
  130 CONTINUE
      CALL B20P
      GO TO 200
C     2 DIMENSIONAL FIELD INPUT,   RECTANGULAR COORDINATES
  150 CONTINUE
      CALL B20R
C
C
  200 CONTINUE
      CALL READIN(IGO)
      GO TO (900,400,400,900,100,100,130,150,500),IGO
  400 CALL ORBIT
      GO TO 200
C
C
C
  500 CONTINUE
      KKPP=0
      KR=(RP2-RP1)/DRP+1.01
      KT=(THE2-THE1)/DTHE+1.01
      TX=AZIMU
      ROR=RP1-DRP
      DO 520 JR=1,KR
      ROR=ROR+DRP
      THE=THE1-DTHE
      DO 520 JT=1,KT
      THE=THE+DTHE
      X0=-ROR*COS(TX)
      Y0=ROR*SIN(TX)
      THETA=TX-THE
      KKPP=KKPP+1
      PRINT 3040,KKPP,KKPP
  520 CALL ORBIT
```

```
      GO TO 200
C
C
C
  930 RETURN
      END
$IBFTC ARKINT
      SUBROUTINE ARKINT
C
C
      INTEGER N,M,FLAG,R,S,J,K,JA
      REAL COFF,T,H,Y,Z,F,A,TEMP,CO,C1,C2,SPACE1
      COMMON FLAG,T,H,Y(14),Z(14),F(4,14)
      DIMENSION COFF(4),TEMP(14),A(4,2)
      DATA N/14/
      DATA M,(COFF(K),K=1,4)/4,2.29166667,-2.45833333,1.54166667,-0.375/
      IF (FLAG .LT. M) GO TO 5142
      T=T+H
      DO 4101 J=1,N
      Z(J)=Y(J)
     1 +A(R+4,1)*F(1,J)+A(R+3,1)*F(2,J)+A(R+2,1)*F(3,J)+A(R+1,1)*F(4,J)
C     SUM A(R+M+1-K)*F(K,J) FOR K=1,M
      Y(J)=Z(J)
 4101 CONTINUE
      R=MOD(R,M) +1
      CALL FUNCT(R)
      RETURN
C
C *RK
C
 5142 CONTINUE
      FLAG=FLAG+1
      IF (FLAG .GT. 1) GO TO 6263
      CO=.5*H
      C1=.166666666*H
      C2=.333333333*H
      DO 4121  JA=1,M
C     AA(JA-M)=AA(JA)=COFF(JA)*H
C     A(L+M,1) IS AA(L) FOR ARRAY AA(-M+1,M)
C     A(L,2) IS AA(L) FOR L BETWEEN 1 AND M.
      A(JA,2)=COFF(JA)*H
      A(JA,1)=A(JA,2)
 4121 CONTINUE
C
      DO 4102  J=1,N
      Z(J)=Y(J)
 4102 CONTINUE
      R=1
      CALL FUNCT (R)
      RETURN
C
C *ST
C
 6263 DO 4103  J=1,N
      Z(J)=Y(J)+CO*F(R,J)
      TEMP(J)=Y(J)+C1*F(R,J)
 4103 CONTINUE
C
      T=T+CO
      CALL FUNCT(M)
      DO 4104  J=1,N



      Z(J)=Y(J)+CO*F(M,J)
      TEMP(J)=TEMP(J)+C2*F(M,J)
 4104 CONTINUE
C
      CALL FUNCT(M)
      DO 4105 J=1,N
      Z(J)=Y(J)+H*F(M,J)
      TEMP(J)=TEMP(J)+C2*F(M,J)
 4105 CONTINUE
C
      T=T+CO
      CALL FUNCT(M)
      DO 4106 J=1,N
      Y(J)=TEMP(J)+C1*F(M,J)
      Z(J)=Y(J)
 4106 CONTINUE
C
      R=MOD(R,M) +1
      CALL FUNCT(R)
      RETURN
      END
$IBFTC BAKSTEP
      SUBROUTINE BAKSTEP(AS)
      COMMON
     1     IFLAG,S,DS,U(14),V(14),DV(4,14),JMAX,KILL,BTBL,
     2     GRAD,PHI,XMAX(8),BZ,XIN(6),BRHO,BRHOI,THETA,BOLD(2)
      COMMON/COM5/AZI,R
      RADD=57.2957795131
      IFLAG=0
      CALL ARKINT
      CALL ARKINT
      AS=ABS(S+BOLD(2))
C
C
      RETURN
      END
$IBFTC B184
      SUBROUTINE B184
C
       DIMENSION U(14),V(14),DV(4,14)
      COMMON IFLAG,S,DS,U,V,DV,JMAX,KILL,BTBL,GRAD,PHI,
     2     XMAX,XMIN,YMAX,YMIN,ZMAX,ZMIN,BX,BY,BZ,XIN,YIN,ZIN,
     2     XO,YO,ZO,BRHO,BRHOI,THETA,
     3  BOLD(2)
      COMMON/BCOM/B(10000)
      COMMON/COM1/IFIELD,NC1,NC2,NR,NA,NB,TABR(200),TABA(200),TABB(200)
      COMMON/COM2/TABR1(200),NB1,RLIM1,RLIM2,RLIM3,RLIM4
      COMMON/COM4/BSCALE,PSCALE,TABB(200)
      COMMON/AJUNK/ R1,R2,DR
 3000 FORMAT(1H1,*MAGNETIC FIELD OF THE 184 INCH CYCLOTRON*//)
 3010 FORMAT(10X10F9.1)
C
C     RADIAL MAGNETIC FIELD DATA FOR THE 184 INCH SYNCHROCYCLOTRON
C     AZIMUTHALLY AVERAGE FIELD       HARMONIC RUNS
C
C
C
      NB=NB1
      R=R1-DR
      DO 50  J=1,NB
      R=R+DR
      TABR1(J)=R
```

```
      X=TABB(J)*BSCALE
      TABB(J)=X
      B(J)=X
   50 CONTINUE
C
C
      PRINT 3010,(TABB(J),J=1,NB)
      PRINT 3010
      PRINT 3010
      PRINT 3010,(TABR1(J),J=1,NB1)
      XMAX=R2
      RLIM2=R2
      XMIN=R1
      RLIM1=R1
      YMIN=-300000.
      YMAX= 300000.
      RETURN
      END
$IBFTC B2DP
      SUBROUTINE B2DP
      RETURN
      END
      SUBROUTINE B2DR
      RETURN
      END
$IBFTC BP184
      SUBROUTINE BP184
C
       DIMENSION U(14),V(14),DV(4,14)
      COMMON IFLAG,S,DS,U,V,DV,JMAX,KILL,BTBL,GRAD,PHI,
     2     XMAX,XMIN,YMAX,YMIN,ZMAX,ZMIN,BX,BY,BZ,XIN,YIN,ZIN,
     2     XO,YO,ZO,BRHO,BRHOI,THETA,
     3  BOLD(2)
      COMMON/BCOM/B(10000)
      COMMON/COM1/IFIELD,NC1,NC2,NR,NA,NB,TABR(200),TABA(200),TABB(200)
      COMMON/COM2/TABR1(200),NB1,RLIM1,RLIM2,RLIM3,RLIM4
      COMMON/COM4/BSCALE,PSCALE,TABB(200)
      DIMENSION CARD(15)
      DIMENSION TABL(200)
 2000 FORMAT(8F10.4)
 2010 FORMAT(I3,2X15F5.0)
 3010 FORMAT(1H ,*PURTURBATIONS */1X*RMIN,RMAX,DR,A1,A2,DA=*6F10.4)
 3020 FORMAT(1H0,*RADIAL MAGNETIC FIELD EXTENDING FROM R=*F8.3,
     1     *TO R=*,  F8.3, * IN 1 INCH STEPS*/
     2     (10X10F10.1) )
 3030 FORMAT(1H0,
     1     3X1HR,8X3H101,5X3H106,5X3H111,5X3H116,5X3H121,5X3H126,
     2     5X3H131,5X3H136,5X3H141,5X3H146,5X3H151,5X3H156,5X3H161,
     3     5X3H166,5X3H171/)
 3040 FORMAT(1XI4,I5,F6.0,14F8.0)
 3050 FORMAT(5X5HSKIP ,I5,2X15F7.0)
 3060 FORMAT(1H )
 3070 FORMAT(1H0,*NR,NA,NB=*3I10)
 3080 FORMAT(1XI5,2X15F8.0)
 3090 FORMAT(1H0,*FIELD PURTURBATIONS BEGIN AT IC=*I3,5X*T(DEG)=(I+1)X5.
     1 *//)
 3100 FORMAT(1H0,*PURTURBATION SUMS        =*F10.1/
     1     1X*PURTURBATION SUMS SKIPPED=*F9.1)
 3110 FORMAT(10X10F8.1)
 3120 FORMAT(1H1,*TOTAL MAGNETIC FIELD PURTURBATIONS*/)


 3130 FORMAT(1H0,*MAGNETIC FIELD PURTURBATIONS*)
 3140 FORMAT(1H0,2XI3)
 4000 FORMAT(1H0,*XMIN,XMAX,YMIN,YMAX=*4F15.3)
C
C
      READ 2000,RMIN,RMAX,DR,A1,A2,DA
      PRINT 3010,RMIN,RMAX,DR,A1,A2,DA
      RD1=1.
      DRR=1.
      K1=IFIX(((RMIN-RD1)/DRR)+1.001)
      K2=IFIX(((RMAX-RD1)/DRR)+1.001)
      JC=K1
      PRINT 3020,RMIN,RMAX,(B(J),J=K1,K2)
      IA1=IFIX(A1)
      IA2=IFIX(A2)
      NA=IA2-IA1+1
      NR=K2-K1+1
      NB=NR*NA
      PRINT 3070,NR,NA,NB
      J1MIN=K1
      J1MAX=K2
      BSUM=0.
      BSUMSP=0.
      R=RMIN-DR
      KO=K1-1
C
C
      DO 100 J=1,200
  100 TABL(J)=TABB(J)
      DO 200 K=1,NR
      R=R+DR
      TABR(K)=R
      KK=KO+K
      JKNA=(K-1)*NA
      DO 200 IAZ=1,NA
      JK=JKNA+IAZ
  200 B(JK)=TABL(KK)*BSCALE
      A=A1-DA
      DO 220 IAZ=1,NA
      A=A+DA
  220 TABA(IAZ)=A
C
C     READ FIELD PERTURBATIONS AT EACH RADIUS FOR 15 AZIMUTHS
C     IF J1.EQ.0 DO NOT USE PURTURBATIONS
C     IF J1.GT.0  READ IN PURTURBATIONS TO RADIAL MAGNETIC FIELD
C
      ICK=0
      PRINT 3130
  400 CONTINUE
      READ 2010,J1,CARD
      IF(J1.GT.0) PRINT 3090,J1
      ICK=ICK+1
      IF(J1.GE.1) GO TO 408
      IF(ICK.EQ.2) GO TO 700
      GO TO 400
  408 IF((J1.GT.IA2).OR.(J1.LT.IA1)) STOP
  410 JOFLD=J1-IA1
      J2=0
  430 CONTINUE
      READ 2010,J1,CARD
      IF(J1.GT.0) GO TO 435
      IF(ICK.EQ.2) GO TO 700
```

```
      GO TO 400
  435 J=J1-KC
      IF((J1.LT.J1MIN).OR.(J1.GT.J1MAX)) GO TO 500
      PRINT 3080,J1,CARD
      IF(J2-J1) 440,450,440
  440 IJOFLD=IJOFLD-15
  450 CONTINUE
      IJOFLD=IJOFLD+1
      DO 470 I=1,15
      IJ=(J-1)*NA+IJOFLD+I
      B(IJ)=B(IJ)+CARD(I)*PSCALE
      BSUM=BSUM+CARD(I)
  470 CONTINUE
      J2=J1
      GO TO 430
      GO TO 400
C
C
  500 PRINT 3050,J1,CARD
      DO 520 J=1,15
  520 BSUMSP=BSUMSP+CARD(J)
      GO TO 430
C
C
  700 CONTINUE
      XMIN=AMIN1(RMIN,RLIM1)
      XMAX=AMAX1(RMAX,RLIM2)
      RLIM3=RMIN
      RLIM4=RMAX
      IF((A2-(A1+1)).GE.359) GO TO 720
      YMIN=A1
      YMAX=A2
  720 CONTINUE
      PRINT 3120
      PRINT 3130,BSUM,BSUMSP
      J1=-NA+1
      J2=0
      DO 800 K=1,NR
      J1=J1+NA
      J2=J2+NA
      KR=K1-1+K
      PRINT 3140,KR
      PRINT 3110,(B(J),J=J1,J2)
  800 CONTINUE
C
C
      PRINT 4000,XMIN,XMAX,YMIN,YMAX
      READ 2010,JUNK
      RETURN
      END

$IBFTC CROSS
      SUBROUTINE CROSS(JTAG,AS)
      COMMON/COM5/AZI,R
      COMMON/COM6/RMATX,TMATX,SMATX,DMATX,MPURGE
C
C
      DR=R-RMATX
      DT=AZI-TMATX
      DS=AS-SMATX
      IF(JTAG)100,900,400
  100 JTAG=4


      JSR=SIGN(1.01,DR)
      JST=SIGN(1.01,DT)
      JSS=SIGN(1.01,DS)
      RETURN
C
C
  400 KSR=SIGN(1.01,DR)
      KST=SIGN(1.01,DT)
      KSS=SIGN(1.01,DS)
      IF(JSR.NE.KSR) JTAG=1
      IF(JST.NE.KST) JTAG=2
      IF(JSS.NE.KSS) JTAG=3
      GO TO (410,420,430,440),JTAG
  410 JSR=KSR
      RETURN
  420 JST=KST
      RETURN
  430 JSS=KSS
  440 RETURN
C
C
  900 CONTINUE
      RETURN
      END
$IBFTC DISCOT

      SUBROUTINE DISCOT(XA,ZA,TABX,TABY,TABZ,NC,N1,NY,NZ,ANS)
C
C     IA=0  EXTRAPOLATION BEYOND ZMAX
C     IA=1 NO EXTRAPOLATION
C     IDX= ORDER OF INTERPOLATION IN X
C     IDZ= ORDER OF INTERPOLATION IN Z
C     IF IDZ=0    Y=F(X),I.E.NO Z DEPENDENCE .............NC=--0
C     IMS=1 IF NC1 IS NEGATIVE I.E.,  NX=NY
C     IMS=0 IF NC1 IS POSITIVE( I.E., NX=NY/NZ
C
C
      DIMENSION TABX(N1),TABY(NY),TABZ(NZ),NPX(8),NPY(8),YY(8)
      CALL UNS (NC,IA,IDX,IDZ,IMS)
      IF(IDZ-1) 5,10,10
    5 CALL DISSER(XA,TABX,1,NY,IDX,NN,N1)
      NNN=IDX+1
      CALL LAGRAN(XA,TABX(NN),TABY(NN),NNN,ANS,N1,NY)
      GO TO 70
   10 ZARG=ZA
      IP1X=IDX+1
      IP1Z=IDZ+1
      IF (IA) 15,25,15
   15 IF (ZARG-TABZ(NZ)) 25,25,20
   20 ZARG=TABZ(NZ)
   25 CALL DISSER (ZARG,TABZ,1,NZ,IDZ,NPZ,NZ)
      NX=NY/NZ
      NPZL=NPZ+IDZ
      I=1
      IF(IMS) 30,30,40
   30 CALL DISSER(XA,TABX,1,NX,IDX,NPX,N1)
      DO 35 JJ=NPZ,NPZL
      NPY(I)=(JJ-1)*NX+NPX(1)
      NPX(I)=NPX(1)
   35 I=I+1
      GO TO 50
   40 DO 45 JJ=NPZ,NPZL
      IS=(JJ-1)*NX+1
      CALL DISSER(XA,TABX,IS,NX,IDX,NPX(I),N1)
      NPY(I)=NPX(I)
   45 I=I+1
   50 DO 55 I=1,IP1Z
      NLOC=NPX(I)
      NLOCY=NPY(I)
   55 CALL LAGRAN (XA,TABX(NLOC),TABY(NLOCY),IP1X,YY(I),N1,NY)
      CALL LAGRAN (ZARG,TABZ(NPZ),YY,IP1Z,ANS,NZ,8)
   70 RETURN
      END

      SUBROUTINE UNS (IC,IA,IDX,IDZ,IMS)
      IF(IC) 5,5,10
    5 IMS=1
      NC=-IC
      GO TO 15
   10 IMS=0
      NC=IC
   15 IF(NC-100)20,25,25
   20 IA=0
      GO TO 30
   25 IA=1
      NC=NC-100
   30 IDX=NC/10
      IDZ=NC-IDX*10
      RETURN
      END

      SUBROUTINE LAGRAN(XA,X,Y,N,ANS,NX,NY)
      DIMENSION X(NX),Y(NY)
      SUM =0.
      DO 3 I=1,N
      PROD=Y(I)
      DO 2 J=1,N
      A=X(I)-X(J)
      IF (A) 1,2,1
    1 B=(XA-X(J))/A
      PROD=PROD*B
    2 CONTINUE
    3 SUM=SUM+PROD
      ANS=SUM
      RETURN
      END

      SUBROUTINE DISSER(XA,TAB,I,NX,ID,NPX,NTAB)
      DIMENSION TAB(NTAB)
C
C
      NPT=ID+1
      NPB=NPT/2
      NPU=NPT-NPB
      IF (NX-NPT) 10,5,10
    5 NPX=I
      RETURN
C
C
   10 NLOW=I+NPB
      NUPP=I+NX-(NPU+1)
      DO 15 II=NLOW, NUPP
      NLOC=II
      IF(TAB(II)-XA)15,20,20


   15 CONTINUE
      NPX=NUPP-NPB+1
      RETURN
C
C
   20 NL=NLOC-NPB
      NU=NL+ID
      DO 25 JJ=NL,NU
      NDIS=JJ
      IF (TAB(JJ)-TAB(JJ+1))25,30,25
   25 CONTINUE
      NPX=NL
      RETURN
C
C
   30 IF (TAB(NDIS)-XA) 40,35,35
   35 NPX=NDIS-ID
      RETURN
C
C
   40 NPX=NDIS+1
C
C
      RETURN
      END


$IBFTC FIELD
      SUBROUTINE FIELD
C
C
      DIMENSION U(14),V(14),DV(4,14)
      COMMON IFLAG,S,DS,U,V,DV,JMAX,KILL,BTOL,GRAD,PHI,
     2    XMAX,XMIN,YMAX,YMIN,ZMAX,ZMIN,BX,BY,BZ,XIN,YIN,ZIN,
     2    XO,YO,ZO,BRHO,BRHOI,THETA,
     3 BOLD(2)
      COMMON/BCOM/B(10000)
      COMMON/COM1/IFIELD,NC1,NC2,NR,NA,NB,TABR(200),TABA(200),TABB(200)
      COMMON/COM2/TABR1(200),NB1,RLIM1,RLIM2,RLIM3,RLIM4
      COMMON/COM3/P,SMAX,SOUT,SPRINT,DSB,MATRIX,IPUNCH
      COMMON/COM4/ESCALE,PSCALE,TAEU(200)
      COMMON/COM5/AZI,R
 3010 FORMAT(1H0,10(1H*),2X*PARTICLE LOCATION OUT OF FIELD RANGE*/
     1    20X*RMIN,R,RMAX=*3F15.3/  20X*AMIN,A,AMAX=*3F15.5//)
C
C
      X=XIN
      Y=YIN
      R=SQRT(X**2+Y**2)
      AZI=57.29578*ATAN2(X,Y)+90.
      IF(AZI.LT.0.) AZI=360.+AZI
      IF(R.GE.XMAX) GO TO 800
      GO TO (700,200,200,500),IFIELD
  200 CONTINUE
      A=AZI
      IF(A.LE.YMIN) GO TO 700
      IF(A.GE.YMAX) GO TO 700
      IF(R.GT.RLIM4) GO TO 700
      IF(R.LT.RLIM3) GO TO 700
  400 CONTINUE
C
C     CALCULATE MAGNETIC FIELD BZ AND GRADIENT DB/DR
```

```
C
      DR=DSB
      R1=R-DR
      R2=R+DR
      CALL DISCOT(A,R,TABA,B,TABR,NC2,NA,NB,NR,BZ)
      CALL DISCOT(A,R1,TABA,B,TABR,NC2,NA,NB,NR,B1)
      CALL DISCOT(A,R2,TABA,B,TABR,NC2,NA,NB,NR,B2)
      GRAD=(B2-B1)/(2.*DR)
      PHI=ATAN2(X,Y)
      BX=0.
      BY=0.
      RETURN
C
C
  500 CONTINUE
C     RECTANGULAR COORDINATES
  700 CONTINUE
      IF(IFIELD.EQ.3) GO TO 800
      R1=R-DSB
      R2=R+DSB
      CALL DISCOT(R,R,TABR1,TABB,TABR1,NC1,NB1,NB1,NB1,BZ)
      CALL DISCOT(R1,R1,TABR1,TABB,TABR1,NC1,NB1,NB1,NB1,B1)
      CALL DISCOT(R2,R2,TABR1,TABB,TABR1,NC1,NB1,NB1,NB1,B2)
      GRAD=(B2-B1)/(2.0*DSB)
      PHI=ATAN2(X,Y)
      BX=0.
      BY=0.
      RETURN
  900 KILL=-1
      PRINT 3010,XMIN,R,XMAX,YMIN,A,YMAX
      BZ=0.0
      GRAD=0.0
      PHI=0.0
C
C
      RETURN
      END

$IBFTC FUNCT
      SUBROUTINE FUNCT(M)
      COMMON IFLAG,S,DS,U,V,DV,JMAX,KILL,BTBL,GRAD,PHI,
     1    XMAX,XMIN,YMAX,YMIN,ZMAX,ZMIN,BX,BY,BZ,XIN,YIN,ZIN,
     2    XO,YO,ZO,BRHO,BRHOI,THETA,
     3  BOLD(2)
      COMMON/BCOM/B(10000)
      DIMENSION U(14),V(14),DV(4,14)
C
C
      XIN=V(1)
      YIN=V(2)
      ZIN=V(3)
      CALL FIELD
      QX=0.0
      QY=0.0
      QZ=BZ*BRHOI
      THETA=ATAN2(V(4),V(5))
      SQK=GRAD*BRHOI*SIN(THETA-PHI)
      SQR=QZ*QZ
C
C
      DV(M,1 )=V(4)
      DV(M,2 )=V(5)


      DV(M,3 )=V(6)
      DV(M,4 )=V(5)*QZ-V(6)*QY
      DV(M,5 )=V(6)*QX-V(4)*QZ
      DV(M,6)=QZ-(SQK+SQR)*V(3)
C
C     HORIZONTAL MATRIX
      DV(M,7 )= V(8 )
      DV(M,8)=-V(7)*(SQK+SQR)
      DV(M,9 )= V(10)
      DV(M,10)=-V(9)*(SQK+SQR)
C
C     VERTICAL MATRIX
      DV(M,11)= V(12)
      DV(M,12)= V(11)*SQK
      DV(M,13)= V(14)
      DV(M,14)= V(13)*SQK
C
C
      RETURN
      END

$IBFTC INITAL
      SUBROUTINE INITAL
C
C
      DIMENSION U(14),V(14),DV(4,14)
      COMMON IFLAG,S,DS,U,V,DV,JMAX,KILL,BTBL,GRAD,PHI,
     1    XMAX,XMIN,YMAX,YMIN,ZMAX,ZMIN,BX,BY,BZ,XIN,YIN,ZIN,
     2    XO,YO,ZO,BRHO,BRHOI,THETA,
     3  BOLD(2)
      COMMON/BCOM/B(10000)
      COMMON/COM1/IFIELD,NC1,NC2,NR,NA,NB,TABR(200),TABA(200),TABB(200)
      COMMON/COM2/TABR1(200),NB1,RLIM1,RLIM2,RLIM3,RLIM4
      COMMON/COM3/P,SMAX,SOUT,SPRINT,DSB,MATRIX,IPUNCH
      COMMON/COM4/BSCALE,PSCALE,TABO(200)
      COMMON/COM6/RMATX,TMATX,SMATX,DMATX,MPURGE
C
C
      NC1=70
      NC2=77
      DSB=.25
      SMAX=50.
      SOUT=50.
      SPRINT =0.
      RMAX=200.
      XMIN=-RMAX
      XMAX=RMAX
      YMIN=-RMAX
      YMAX=RMAX
      SMAX=100.
      JMAX=500
      ZMAX=1.0E10
      ZMIN=-1.0E10
      BSCALE=1.
      PSCALE=1.
      MATRIX=1
      IPUNCH=0
      RMATX=100000.
      TMATX=100000.
      SMATX=100000.
      DMATX=0.
      MPURGE=1
C
C
      RETURN
      END

$IBFTC ORBIT
      SUBROUTINE ORBIT
C
C
      DIMENSION U(14),V(14),DV(4,14)
      COMMON IFLAG,S,DS,U,V,DV,JMAX,KILL,BTBL,GRAD,PHI,
     1    XMAX,XMIN,YMAX,YMIN,ZMAX,ZMIN,BX,BY,BZ,XIN,YIN,ZIN,
     2    XO,YO,ZO,BRHO,BRHOI,THETA,
     3  BOLD(2)
      COMMON/BCOM/B(10000)
      COMMON/COM1/IFIELD,NC1,NC2,NR,NA,NB,TABR(200),TABA(200),TABB(200)
      COMMON/COM3/P,SMAX,SOUT,SPRINT,DSB,MATRIX,IPUNCH
      COMMON/COM4/BSCALE,PSCALE,TABO(200)
      COMMON/COM5/AZI,R
      COMMON/COM6/RMATX,TMATX,SMATX,DMATX,MPURGE
C
C
 2000 FORMAT(10X5F10.5)
 2010 FORMAT(5F10.5,I10)
 3010 FORMAT(1X15,F9.3,2F9.3,2F10.4,1XF12.3,F5.1,1XF5.4)
 3040 FORMAT(1H0,2X1HJ,2X7HS(INCH),4X7HX(INCH),2X7HY(INCH),2X7HR(INCH),
     1    2X7HAZ(DEG),5X5HINDEX,5X8HB(GAUSS),1CX8HOPHI(DEG)   )
C
C
      PRINT 3040
      MFLAG=0
      J=SPRINT/ABS(DS)+.01
      JPSTEP=MAXO(J,1)
      J=SOUT/ABS(DS)+.01
      JMSTEP=MAXO(J,1)
      KILL=0
      JSTOP=DMATX+.1
      BOLD(2)=S
      S=0.
      JBOLD1=BOLD(1)+.0001
      IF(JBOLD1.NE.8) CALL START
      SX1=BOLD(2)
      RADD=57.2957795131
      IFLAG=0
      RRO=SQRT(XO**2+YO**2)
      AS= ABS(SX1)
      JTAG=-1
      IF(MPURGE.EQ.1) JTAGE=C
      CALL CROSS(JTAG,AS)
C
C
C
C     MAIN LOOP
C
      DO 300 J=1,JMAX
      CALL ARKINT
      IF(KILL.EQ.-1) GO TO 390
      X=U(1)
      Y=U(2)
      AS=ABS(S+SX1)
C
C


      CALL CROSS(JTAG,AS)
      IF(JTAG.LT.1.OR.JTAG.GT.3) GO TO 175
C
C
      DS1=DS
      RX=R
      ASX=AS
      AZX=AZI
      DS=-DS
      CALL BAKSTEP(AS)
      GO TO (124,128,120),JTAG
  120 DS=(SMATX-AS)*DS1/(ASX-AS)
      GO TO 130
  124 DS=(RMATX-R)*DS1/(RX-R)
      GO TO 130
  128 DS=(TMATX-AZI)*DS1/(AZX-AZI)
  130 CONTINUE
      CALL BAKSTEP(AS)
      X=U(1)
      Y=U(2)
      PHOUT=90.-RADD*(THETA-PHI)
      IF(PHOUT.GT.180.) PHOUT=PHOUT-360.
      BB=AMAX1(ABS(BZ),.1)
      AN=-GRAD*R/BB
      SS=AS
      PRINT 3010,J,SS,X,Y,R,AZI,AN,BZ,PHOUT
      CALL OUTFIT
      IF(JTAG.EQ.JSTOP) GO TO 360
      PRINT 3040
  140 DS=DS1-DS
      CALL BAKSTEP(AS)
      DS=DS1
      IFLAG=0
      CALL ARKINT
      JTAG=4
  175 CONTINUE
C
C
      IF(MOD(J-1,JPSTEP)) 250,230,250
  230 CONTINUE
      GROUT=-GRAD
      PHOUT=90.-RADD*(THETA-PHI)
      IF(PHOUT.GT.180.) PHOUT=PHOUT-360.
      BB=AMAX1(ABS(BZ),.1)
      AN=GROUT*R/BB
      SS=AS
      PRINT 3010,J,SS,X,Y,R,AZI,AN,BZ,PHOUT
  250 CONTINUE
      IF(MOD(J-1,JMSTEP))290,280,290
  280 IF(J.EQ.1) GO TO 290
      CALL OUTFIT
      PRINT 3040
  290 IF(KILL.EQ.-1.OR.AS.GT.SMAX) GO TO 390
  300 CONTINUE
      GO TO 390
C
C     END MAIN LOOP
C
C
C
C
  380 DS=DS1
```

```
C
  990 CONTINUE
      RETURN
      END
$IBFTC OUTFIT
      SUBROUTINE OUTFIT
C
C
      DIMENSION U(14),V(14),DV(4,14)
      COMMON IFLAG,S,DS,U,V,DV,JMAX,KILL,BTBL,CRAD,PHI,
     2    XMAX,XMIN,YMAX,YMIN,ZMAX,ZMIN,BX,BY,BZ,XIN,YIN,ZIN,
     2    X0,Y0,Z0,BRHO,BRHOI,THETA,
     3 BOLD(2)
      COMMON/BCOM/B(10000)
      COMMON/COM1/IFIELD,NC1,NC2,NR,NA,NB,TABR(200),TABA(200),TABB(200)
      COMMON/COM3/P,SMAX,SOUT,SPRINT,DSH,MATRIX,IPUNCH
      COMMON/COM4/BSCALE,PSCALE,TABU(200)
      COMMON/COM5/AZI,R
C
C
 2000 FORMAT(10X5F10.5)
 2010 FORMAT(5F10.5,I10)
 3010 FORMAT(1XI5,F9.2,2X2F9.2,2F9.3,2XE12.3,F5.1,10XF5.3)
 3020 FORMAT(15X5F10.5,10X5F10.5)
 3030 FORMAT(15X14(1H-),14HFORWARD MATRIX,18(1H-),10X18(1H-),
     U      *REVERSE MATRIX*,14(1H-))
 3040 FORMAT(1H ,17X*RADIAL DETM=*F10.6,3X*VERTICAL DETM=*F10.6)
      DIMENSION MA(4),RMA(4,5),RMAI(4,5),UU(5,4,3)
      DATA RMA/20*0./
      DATA RMAI/20*0./
      DATA MA/2,1,4,3/
C
C     T/AJ  MATRIX CONVENTION          +B BEND LEFT FOR ELECTRONS
C                WITH +X AXIS TO LEFT
C     TRANSPORT MATRIX CONVENTION      +B BEND LEFT FOR ELECTRONS
C                WITH +X AXIS TO RIGHT
      DATA UU/ 1.,.001,0.,0.,-.01,    1000.,1.,0.,0.,-10.,
     1    0.,0.,1.,.001,0.,           0.,0.,1000.,1.,0.,
     2    1.,1.,0.,0.,1.,             1.,1.,0.,0.,1.,
     3    0.,0.,1.,1.,0.,             0.,0.,1.,1.,0.,
     4    20*0.  /
C
C
C
C     MATRIX
C
      PRINT 3010
      II=6
      N=-2
      DO 220 IJ=1,2
      N=N+2
      DO 216 KJ=1,2
      DO 216 JK=1,2
      II=II+1
      N1=JK+N
      N2=KJ+N
  216 RMA(N1,N2)=U(II)
      I6=IJ*3
      RMA(IJ,5)=U(I6)
  220 CONTINUE
      DO 230 JJ=1,4
      DO 230 KK=1,5


  230 RMA(JJ,KK)=RMA(JJ,KK)*UU(KK,JJ,MATRIX)
      DO 240 JJ=1,4
      N=MA(JJ)
      RMAI(JJ,JJ)=RMA(N,N)
  240 RMAI(JJ,N)=-RMA(JJ,N)
      RMAI(1,5)=RMA(1,2)*RMA(2,5)-RMA(2,2)*RMA(1,5)
      RMAI(2,5)=RMA(2,1)*RMA(1,5)-RMA(1,1)*RMA(2,5)
      DETR=RMA(1,1)*RMA(2,2)-RMA(1,2)*RMA(2,1)
      DETZ=RMA(3,3)*RMA(4,4)-RMA(3,4)*RMA(4,3)
      PRINT 3030
      PRINT 3020,((RMA(JJ,KK),KK=1,5),(RMAI(JJ,KJ),KJ=1,5),JJ=1,4)
      PRINT 3040,DETR,DETZ
      IF(IPUNCH.EQ.1) WRITE(2,2010)(((RMA(J1,J2),J2=1,5),J1),J1=1,4)
C
      IF(KILL.EQ.-1.AND.IPUNCH.EQ.1) GO TO 400
      RETURN
C
C
  400 REWIND 2
      KJ=IFIX(S/SOUT)-1
      DO 440 J=1,KJ
      READ(2,2010)(((RMA(J1,J2),J2=1,5),J1),J1=1,4)
  440 PRINT 2000,((RMA(J1,J2),J2=1,5),J1=1,4)
      RETURN
C
C
      END
$IBFTC READIN
      SUBROUTINE READIN(IGO)
      DIMENSION U(14),V(14),DV(4,14)
      COMMON IFLAG,S,DS,U,V,DV,JMAX,KILL,BTBL,CRAD,PHI,
     2    XMAX,XMIN,YMAX,YMIN,ZMAX,ZMIN,BX,BY,BZ,XIN,YIN,ZIN,
     2    X0,Y0,Z0,BRHO,BRHOI,THETA,
     3  BOLD(2)
      COMMON/BCOM/B(10000)
      COMMON/COM1/IFIELD,NC1,NC2,NR,NA,NB,TABR(200),TABA(200),TABB(200)
      COMMON/COM3/P,SMAX,SOUT,SPRINT,DSH,MATRIX,IPUNCH
      COMMON/COM4/BSCALE,PSCALE,TABU(200)
      COMMON/COM6/RMATX,TMATX,SMATX,DMATX,MPURGE
      COMMON/COM7/RP1,RP2,DRP,AZIMU,THE1,THE2,ETHE
      COMMON/CARKI/ NEGNN
      DIMENSION X(8)
 2000 FORMAT(8F10.0)
 2020 FORMAT(8A10)
 3010 FORMAT(1H1)
 3020 FORMAT(1H0,*P(GEV/C)=*F10.7/
     1      1X*DS(INCHES)=*F8.3/1X*BR(KG-IN)=*E12.4/1X*E(GEV)=*F10.7  )
 3030 FORMAT(1H0,*INPUT DATA =*1X8F12.6)
 3040 FORMAT(10X8A10)
      DATA RAD,EI/.01745329,.9382137/
      PI=3.14159
      PI2=6.28318
C
      BOLD(1)=0.
      PRINT 3010
  100 CONTINUE
      IPUNCH=0
  110 CONTINUE
      READ 2000,(X(J),J=1,8)
      IGO=IFIX(X(1)+.0001) +1
      GO TO (110,200,200,400,550,500,600,650,700,750,990),IGO
C
C
  200 CONTINUE
      IF(ABS(X(5)).LE.1.0E-6) GO TO 210
      E=X(5)
      SS=SIGN(1.,E)
      E=ABS(E)
      P=SQRT(E**2+2.*E0*E)
      P=P*SS
      BRHO=.1313247/P
      BRHOI=1.0/BRHO
  210 CONTINUE
      IF(ABS(X(6)).NE.0.) DS=X(6)
      IF(X(7).GT.0.)  SMAX=X(7)
      IF(X(8).GT.0.)  SOUT=X(8)
      JMAX=(SMAX/ABS(DS))+1.1
  220 PRINT 3030,(X(J),J=1,8)
      PRINT 3020,P,DS,BRHO,E
C
C     INPUT PARTICLE LOCATION
C
  300 X0=X(2)
      Y0=X(3)
      IF(JPHIIN.EQ.1) X(4)=57.2957795131*ATAN(X(4))
      THETA=RAD*X(4)
      IF(IGO.EQ.3) GO TO 320
      R=X0
      TX=Y0*RAD
      X0=-R*COS(TX)
      Y0=R*SIN(TX)
      THETA=TX-THETA
  320 CONTINUE
      RETURN
C
C
  400 CONTINUE
      PRINT 3030,(X(J),J=1,3)
      K=IFIX(X(2)+.0001)
      IF(K.GT.10) GO TO 100
      GO TO (410,420,430,440,450,460,470,480,490,495),K
  410 NC2=IFIX(X(3)+.00001)
      NC1=NC2-MOD(NC2,10)
      GO TO 100
  420 E0=X(3)
      GO TO 100
  430 SMAX=X(3)
      GO TO 100
  440 SOUT=X(3)
      GO TO 100
  450 CONTINUE
      JMAX=IFIX(X(3))
      GO TO 110
  460 SPRINT=X(3)
      GO TO 100
  470 MATRIX=X(3)
      NEGNN=14
      GO TO 100
  480 IPUNCH=X(3)
      GO TO 100
  490 JPHIIN=X(3)+.01
      GO TO 100
  495 CONTINUE
      DS=X(3)


      JMAX=(SMAX/ABS(DS))+1.1
      GO TO 100
C
C
C     SPECIFY LOCATION OF DESIRED OUTPUT MATRIX
C          5.   1.   R
C          5.   2.   THETA
C          5.   3.   S
C          5.   4.   DMATX.
C          5.   5.   TURN OFF MATRIX OPTION (PURGE)
C
  500 CONTINUE
      IGO=4
      PRINT 3030,(X(J),J=1,3)
      K=IFIX(X(2)+.01)
      IF(K.GT.5) GO TO 100
      GO TO (510,520,530,540,545),K
  510 RMATX=X(3)
      GO TO 549
  520 TMATX=X(3)
      GO TO 549
  530 SMATX=X(3)
      GO TO 549
  540 DMATX=X(3)
      GO TO 549
  545 RMATX=1000000.
      TMATX=1000000.
      SMATX=1000000.
      MPURGE=1
      GO TO 100
  549 MPURGE=0
      GO TO 100
C
C
C
  550 CONTINUE
      PRINT 3010
      PRINT 3030,(X(J),J=1,4)
      IF(ABS(X(3)).GT.0.) BSCALE=X(3)
      PSCALE=BSCALE
      IF(ABS(X(4)).GT.0.) PSCALE=X(4)
      IFIELD=IFIX(X(2)+.00001)
      IGO=IGO+IFIELD-1
      RETURN
C
C
  600 N=X(2)+.01
      PRINT 3030,(X(J),J=1,2)
      DO 610 J=1,N
      READ 2020,X
  610 PRINT 3040,X
      GO TO 110
C
C     7.
C
  650 PRINT 3030,(X(J),J=1,8)
      IF(X(4).LT.1.0E-10) X(4)=1.
      IF(X(8).LT.1.0E-10) X(8)=1.
      RP1=X(2)
      RP2=X(3)
      DRP=X(4)
      AZIMU=X(5)*RAD
```

```
      THE1=X(6)*RAD
      THE2=X(7)*RAD
      DTHE=X(8)*RAD
      IGO=9
      RETURN
C
C     8.
C
  700 CONTINUE
      PRINT 3030,X(1)
      BOLD(1)=8.
      IGO=2
      RETURN
C
C
  750 PRINT 3010
      GO TO 110
  890 IGO=1
  900 RETURN
      END
$IBFTC START
      SUBROUTINE START
C
C
C
C
C        NAME        V()        U()         INITAL U() VALUE
C       ------      ------     ------      --------
C         1         XIN        X           XO
C         2         YIN        Y           YO
C         3         ZIN        M15         0
C         4                    DY/DS       SIN(THETA)
C         5                    DX/DS       COS(THETA)
C         6                    M25         0.
C         7         HORIZ      M11         1.
C         8         HORIZ      M21         0.
C         9         HORIZ      M12         0.
C        10         HORIZ      M22         1.
C        11         VERTICAL   M33         1.
C        11         VERTICAL   M43         0.
C        12         VERTICAL   M43         0.
C        13         VERTICAL   M34         0.
C        14         VERTICAL   M44         1.
C
C
C
C
C
      COMMON
     1     IFLAG,S,DS,U(14),V(14),DV(4,14),JMAX,KILL,BIBL,
     2     GRAD,PHI,XMAX,XMIN,YMAX,YMIN,ZMAX,ZMIN,
     3     BX,BY,BZ,XIN,YIN,ZIN,XO,YO,ZO,BREC,EFHGI,THETA,
     4     BOLD(2)
      COMMON/BCOM/B(10000)
      COMMON/COM5/AZI,R
C
C
      BOLD(2)=0
      U(1)=XO
      U(2)=YO
      U(3)=0
      U(4)=SIN(THETA)


      U(5)=COS(THETA)
      U(6)=0
      U(7)=1.
      U(9)=0
      U(9)=0
      U(10)=1.
      U(11)=1.
      U(12)=0
      U(13)=0
      U(14)=1.
      R=SQRT(XO*XO+YO*YO)
      AZI=57.29578*ATAN2(XO,YC)+90.
      IF(AZI.LT.0) AZI=360.+AZI
C
C
      RETURN
      END
```

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