

KEK Internal 2001-4
June 2001
R/D

EGS4 Shower Display System
(EGS4PICT)
Windows 32 Bits Version
Revised 10/31/2002

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High Energy Accelerator Research Organization

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(EGS4PICT)
Windows 32 Bits Version**

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Abstract

The EGS4PICT was upgraded to increase the precision of the position coordinates. Several improvements, like a change of the window size by mouse, were also made.

1 Introduction

The EGS4 Shower Display System (EGS4PICT) is widely used within the EGS4 users' community as an easy tool for the three-dimensional particle trajectories of electrons, positrons and photons on a personal computer (PC).

In the current version[1, 2], a position coordinate is limited to a number with 5 digits. It is desired to increase the effective digit so as to see more details of trajectories by an expansion function. In this Windows 32 bits version, it become possible to treat 8 as an effective digit together with 5.

It has become possible to change the display window size in an arbitrary manners using a mouse and to put a dot even in the case when a produced particle is discarded.

2 Outline of EGS4PICT Windows 32 Bits Version

The EGS4PICT Windows 32 bits version is a system used to display the trajectories of electrons, positrons and photons, which are calculated using the EGS4 Monte Carlo code[3], semi-interactively on a PC.

It has the following functions:

- Activates the Command prompt (MS-DOS prompt) to run EGS4, which creates the trajectory data for display
- Expands the designated area
- Rotates around the X-, Y-, and Z-axis
- Changes the color and type of line for each particle
- Selects the batch number or the batch range to be displayed¹
- Displays the title and scale
- Selects the type of particle to display
- Sets the lowest energy of a particle to display
- Displays the geometry in the case of a plane, cylinder or plane and cylinder.
- Outputs the display on the file in the bitmap (bmp) format
- Outputs the display to the printer

The system works on a PC with the Microsoft Windows 9x/Me/NT/2000.

3 Structures of the Trajectory Data

To reduce the data size of a trajectory, the position and energy of each particle are expressed by a number comprising five or eight figures.

One record is composed from '*abbbbccccddddd $efghi$* ' or '*abbbbbbbccccccccddddd $efghi$* '. The meaning of each character is as follows:

¹The number of history per batch depends on the user code. It is possible to include any number of history per batch.

a: variable to indicate the type of the record
 0 \implies start of the new history
 1 \implies 5 digit position data of photon
 2 \implies 5 digit position data of electron
 3 \implies 5 digit position data of positron
 4 \implies 8 digit position data of photon
 5 \implies 8 digit position data of electron
 6 \implies 8 digit position data of positron
 -1 \implies change to different type of particle
 9 \implies end of batch

If $a = 0$, *bbbb* follows after *a*.

bbbb: the batch number.

If $a=1, 2$ or 3 , '*bbbbccccddddefgh*' follows.

bbbb: X-coordinate

cccc: Y-coordinate

dddd: Z-coordinate

efghi: kinetic energy of the particle

If $a=4, 5$, or 6 , '*bbbbbbccccccccdddddddefgh*' follows.

bbbbbbb: X-coordinate

ccccccc: Y-coordinate

ddddddd: Z-coordinate

If $a=-1$ or 9 , no character follows.

The X-, Y-, and Z-coordinates are expressed as integers in order to reduce the data size. To express a wide range of data depending on each problem, the coordinate is normalized with FNORM by one of following equations:

$$bbbb = INT(x/FNORM * 10000) + 50000, \quad (1)$$

or

$$bbbbbbb = INT(x/FNORM * 8388608) + 33554432. \quad (2)$$

Inside the display program, '*bbbb*' or '*bbbbbbb*' is converted to a real coordinate by

$$x = (bbbb - 50000)/100000 * FNORM, \quad (3)$$

or

$$x = (bbbbbbb - 33554432)/8388608 * FNORM. \quad (4)$$

The *efghi* is converted to kinetic energy in MeV by

$$E(MeV) = efgh \times 10^{i-3}. \quad (5)$$

In this way, it is possible to express the energy range from 1 keV to 9.9999×10^9 MeV using number with five figures to the same precision.

4 EGS4PICT System Windows 32 Bits Version

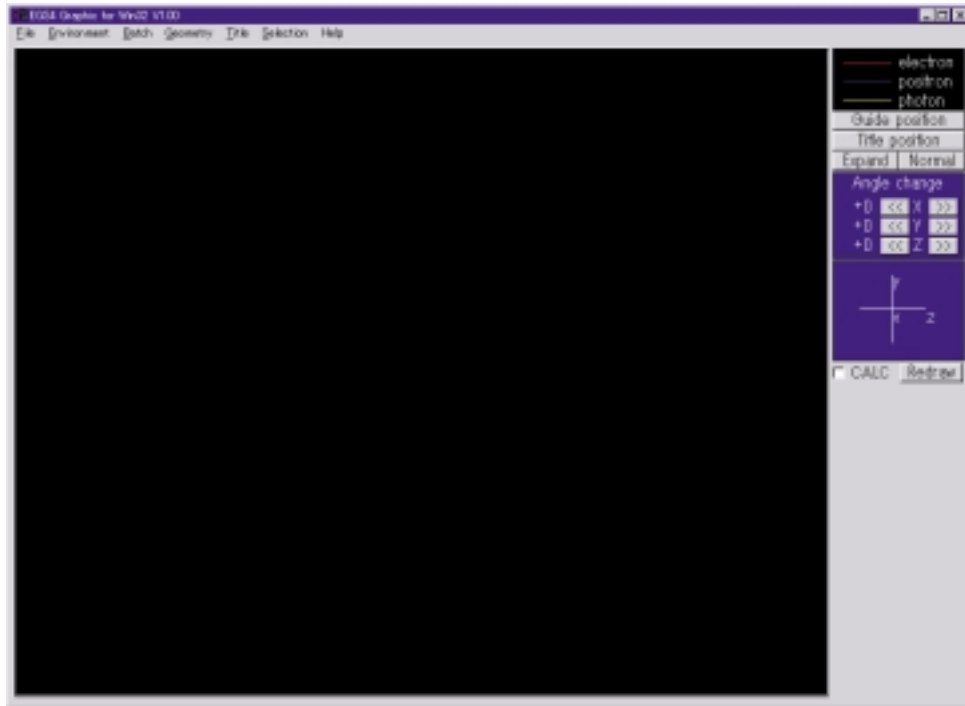
4.1 Hardware requirement

The EGS4PICT system Windows 32 bits version runs under the following hardware situation:

- Personal computer (PC) - Operating with the Microsoft Windows 9X/Me/NT/2000
- Memory - minimum 4MB
- Hard disk - \sim 1MB.

4.2 Main display

When you double click EGS4win32.exe, the following display appears first.

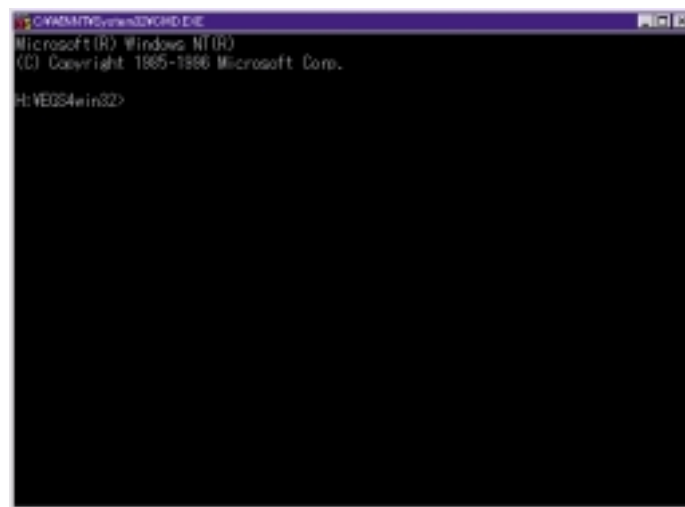


4.2.1 Display size

The display size can be changed by dragging the edge of the display window.

4.2.2 Calc and Redraw

If "CALC" is selected, the Command prompt (MS-DOS prompt) becomes active. You can run the EGS4 calculation, which creates particle trajectories from this Command prompt.



When the user code written to close the file of the trajectories after the current batch has finished, you can draw trajectories of the current batch by selecting "Redraw".

If you select the “CALC” function, the Command prompt again becomes active. You can re-start the EGS4 calculation from this Command prompt.

4.2.3 Guide position

Guidance to show the color and the line type of each particle can be included inside the display window by clicking the guide position. You can display this guide box at any place by clicking at the position that you want to display. The ESC-key cancels this procedure.

4.2.4 Title position

The title of the shower picture written by 'title' can be included inside the display window by clicking the title position. You can display the title at any place by clicking at the position that you want to display. The ESC-key cancels this procedure.

4.2.5 Expand

Any part of the shower the picture can be expanded by clicking on the Expand box. Push the left button of the mouse at the start point (the upper left) and drag until the end point (the lower right). It is possible to expand any part of the expanded picture by using the same procedure. The ESC-key cancels this procedure.

If the Normal box is clicked, the expanded display is canceled and the original display appears.

4.2.6 Angle change

The angle change is a function used to change the view angle of each coordinate with the angle step value determined at “Angle step” in the environment.

If the >> button or the << one of x is clicked by the mouse, the x-axis rotates counter-clockwise or clockwise, respectively. The situation of the coordinate is shown at the box below that of the angle change.

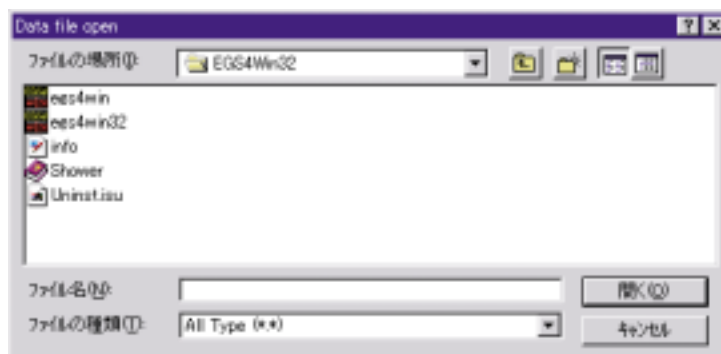
4.3 Menu bar

4.3.1 File

The file has the following pull-down menu:



Data File Open If “Data File Open” is selected, the following data file window appears. The file name created by using EGS4 for EGS4PICT must be defined with the full path by selecting the directory and file.



Bitmap File Open If “Bitmap File Open” is selected, the “Data File Open” window appears. You can define a file name by saving the trajectories window in bitmap.

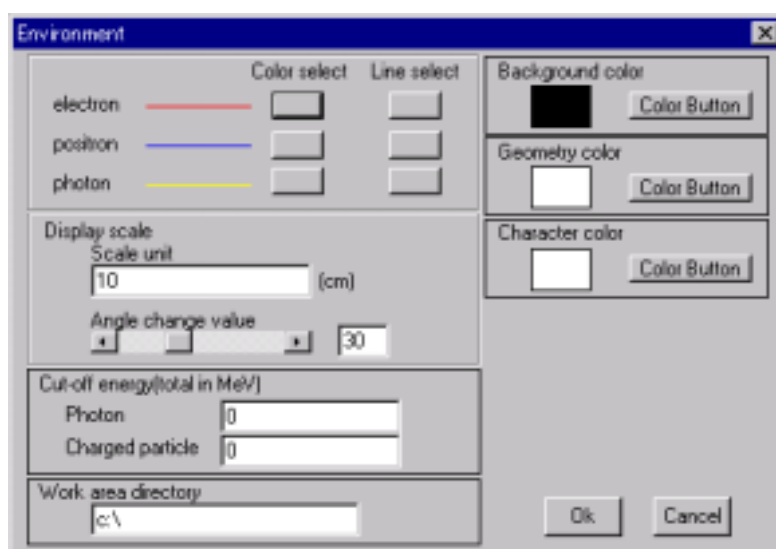
Print Print out the shower picture displayed on the screen to the printer. The printer is selected using the “Printer Setup” menu.

Printer Setup Select the printer and change the established items.

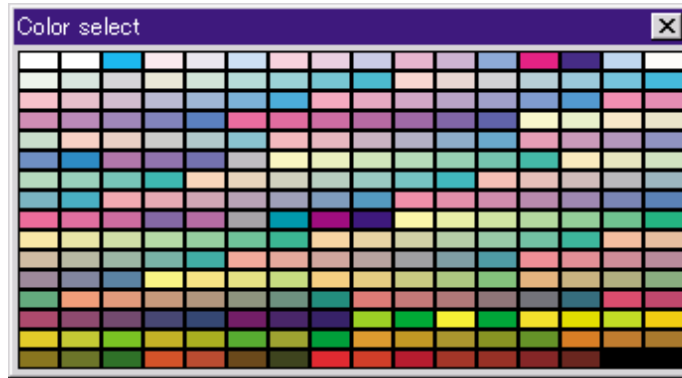
End Exit the EGS4PICT system. After finishing the system, the established conditions are stored in the information file (info.\$\$\$).

4.3.2 Environment

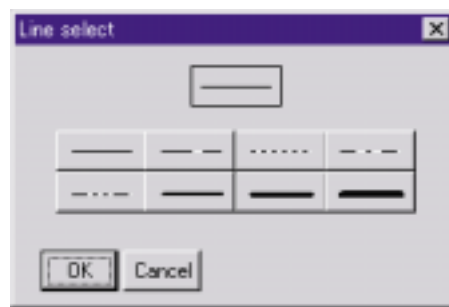
If “Environment” is selected, the following environment window appears:



Color select The colors of an electron, positron or photon are selected from the following color-selection pallet. If the colors possible to use are less than 256, a color-selection pallet including only 16 colors appears. A color is determined by clicking at the mouse left button.



Line select The line type of an electron, positron or photon is selected from the following line-type selection window:



Scale unit Define the unit of the scale in cm. The default value is 0.1.

Angle change value Define any change in the view angle of each axis with one mouse click. The default value is 30 degrees.

Cut-off energy Define the cut-off energy in the total energy below that energy for which the trajectory is not drawn.

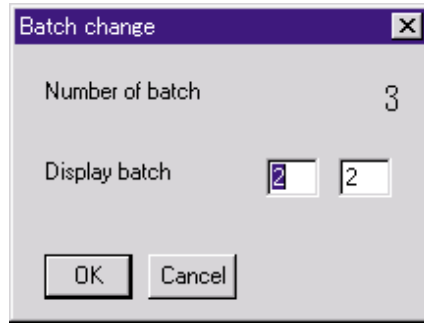
Workfile Define the directory to make a workfile.

Background, Geometry and Character color Change the background, geometry or character color. If the “Color Button” of corresponding item is clicked, the color-selection pallet appears, as mentioned for “Color select”.

4.3.3 Batch

Define the batch region to be displayed in the following window. If the start number is left blank, the batch is set to 1. If the end batch is set to blank, the end batch is set to the number of batch including the data file:

- [] ~ [] --draw all batch
- [2] ~ [] --draw batch from 2 to last
- [] ~ [4] --draw batch from first to 4
- [2] ~ [3] --draw batch from 2 to 3



4.3.4 Geometry

Define the geometry file. This may be used for the future development of drawing complex geometry. The “Geometry Hide” box is used to on/off the geometry drawing.

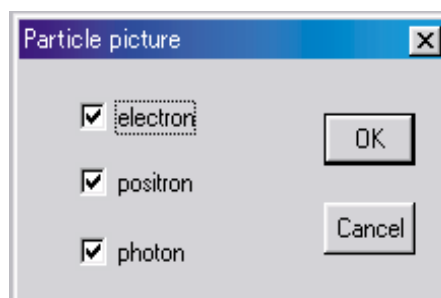
4.3.5 Title

Write the title of the picture in the following window.



4.3.6 Selection

On/off the drawing of each type of particle.



5 EGS4 User Code for EGS4PICT Windows 32 Bits Version

For drawing the trajectories of the particles, it is necessary to obtain a series of data, which include the type of particle as well as its position and geometry. These data must be output as a group for the type of particle and associated position in the way mentioned in “Structures of the Trajectory Data”. In the EGS4 calculation, a particle having a smaller total energy is followed first after the interaction. When the type of particle followed is different from that of the current particle, the group of data must be written on the output file.

SUBROUTINE PLOTXYZ was developed by modifying SUBROUTINE PLOTXZ[4], which was developed at SLAC for a 2-dimensional shower display using the Unified Graphics System and presented as the key SUBROUTINE in Ref.[1] together with SUBROUTINE GEOMOUT, which made the data for drawing the cylinder-slab or the slab geometry. The coordinates are transferred into a number of five or eight figures in

SUBROUTINE PLOTXYZ in this reference. The EGS4PICT Windows 32bit System can draw the trajectories made using this PLOTXYZ.

SUBROUTINE PLOTXYZ was modified corresponding to the new features of EGS4PICT. The EGS4 user code to obtain data concerning the particle trajectories for EGS4PICT is explained below using uc pict4_32.mor, which is the user code to obtain shower display data of ucsampl4.mor; lists of it are given in Appendix.

5.1 Main Program

The statements that are necessary for EGS4PICT have a comment “PICT” at the right side. In the main program, the following statements must be added.

1. COMMON/NFAC/FNORM,XMIN,XMAX,YMIN,YMAX,ZMIN,ZMAX,NPRECI ;
The FNORM is the maximum size of the range to be displayed between X-, Y- and Z-coordinate. XMIN, YMIN and ZMIN are the minimum values in the X-, Y- and Z-coordinate, respectively. XMAX, YMAX and ZMAX is the maximum one.
NPRECI is the new flag to specify the precision of the position coordinate.
2. OPEN(9,file='mortjob.pic',status='unknown') ;
Define the file name to which the data of the shower display are written.
3. XMIN=-5.0; XMAX=5.0; YMIN=-5.0; YMAX=5.0;
ZMIN=-1.0; ZMAX=ZTHICK+2.0*ZAIR+2.0;
Define the region that you want to display at each coordinate.
4. CALL GEOMOUT(NCYL,NPLAN) ;
Call SUBROUTINE GEOMOUT to output the geometry data. NCYL is the number of cylinder and NPLAN the number of planes. If the geometry is constructed by the plane only, like this example, NCYL is set to 0.
As data of cylinders and/or planes, CYRAD2 and/or PNORM and PCOORD, which are used in EGS4 geometry subroutines or macros, are used.
5. FNORM=AMAX1(XMAX-XMIN,YMAX-YMIN,ZMAX-ZMIN) ;
Calculate the maximum size to be displayed in the X-, Y- and Z-coordinate.
6. WRITE(9,:FMT90:) XMIN,XMAX,YMIN,YMAX,ZMIN,ZMAX,FNORM ;
:FMT90:FORMAT(7E10.3) ;
Output the region to be displayed at each coordinate and the normalization factor.
7. NPRECI=1 ;
Define the flag to specify the precision of the position coordinates. 0 and 1 mean that the precision of the X-, Y-, Z-coordinate are expressed in 5 and 8 digits, respectively.

8. `WRITE(9, :FMT91:) III; :FMT91:FORMAT('0', I5);`
Output the '0' which indicates the start of the batch number.
9. `WRITE(9, :FMT92:); :FMT92:FORMAT('9');`
Output '9' which indicates the end of the history.
10. `CALL PLOTXYZ(99, 0, 0, 0., 0., 0., 0.DO);`
Tell SUBROUTINE PLOTXYZ that all of the histories in the batch are finished. If the first argument is 99, all the data that are not written on the output file are outputted in PLOTXYZ.

5.2 SUBROUTINE AUSGAB

Each time when the SUBROUTINE AUSGAB is called, IARG, the stack number (NP), the type of particle (IQ(NP)), the position of the particle (X(NP), Y(NP), Z(NP)) and the energy of particle (E(NP)) are transferred to the SUBROUTINE PLOTXYZ by the following statement:

```
CALL PLOTXYZ(IARG, NP, IQ(NP), X(NP), Y(NP), Z(NP), E(NP));
```

5.3 SUBROUTINE PLOTXYZ

SUBROUTINE PLOTXYZ was written based on SUBROUTINE PLOTXZ developed at SLAC for the 2-dimensional display of a shower picture.

To express the coordinates using a number having five or eight figures and the energy of a particle using a number having five figures, the following statements are used:

```
IF(NPRECI.EQ.0) [
IXPT(NPT(NP), NP)=X/FNORM*10000+50000;
IYPT(NPT(NP), NP)=Y/FNORM*10000+50000;
IZPT(NPT(NP), NP)=Z/FNORM*10000+50000;
]
ELSE [
IXPT(NPT(NP), NP)=X/FNORM*8388608+33554432;
IYPT(NPT(NP), NP)=Y/FNORM*8388608+33554432;
IZPT(NPT(NP), NP)=Z/FNORM*8388608+33554432;
]

IF(IQ.EQ.0) [EEE=ENP*1000.;]
ELSE [EEE=(ENP-0.511)*1000.]
IF(EEE.LT.10000.0) [
IEPT(NPT(NP), NP)=INT(EEE)*10;]
ELSE [
IFF=ALOG10(EEE)-3;
IEF=EEE/10**IFF;
IEPT(NPT(NP), NP)=IEF*10+IFF;]
```

SUBROUTINE PLOTXYZ stores the coordinates, the energy and the type of particle at each NP with a number from 1 to 100. When the type of the particle changes in the same NP or the stored number becomes 100, the stored data are written in the output file. The last stored data are set to the data number 1. These procedures are those developed in SUBROUTINE PLOTXZ.

5.4 SUBROUTINE GEOMOUT

The current version treats only the cylinder-slab geometry and the plane geometry. If NCYLG is not 0, the cylinder-slab geometry is selected. If NCYLG is zero and NSLAB is not zero, the plane geometry is selected. If both NCYLG and NSLAB are 0, geometry data are not produced.

1. the cylinder-slab geometry

```

GSTA
CYLS
NCYLG,NZP          <---- NCYLG: number of cylinders,
                   NZP: number of Z-axis planes
CYL(I),I=!,NCYLG  <---- radius of the cylinders
ZBIN(I),I=1,NZP   <---- coordinate of Z-axis planes
GEND

```

2. the plane geometry

```

GSTA
SLAB
NXP,NYP,NZP        <---- number of X-, Y- and Z-axis planes,
                   respectively
XBIN(I),I=1,NXP    <---- coordinate of X-axis planes
YBIN(I),I=1,NYP    <---- coordinate of Y-axis planes
ZBIN(I),I=1,NZP    <---- coordinate of Z-axis planes
GEND

```

3. Other case

```

GSTA
GEND

```

6 How to Modify the User Code Written for a Previous Version

The EGS4 user code written for a previous version of EGS4PICT can be applied to EGS4PICT Windows 32 Bits Version by following modifications:

1. Add NPRECI to COMMON/NFAC like
COMMON/NFAC/FNORM,XMIN,XNAX,YMIN,YMAX,ZMIN,ZMAX,NPRECI ; .
2. Insert NPRECI=1; at the Step 6 in the main program.
3. Replace SUBROUTINE PLOTXYZ; and SUBROUTINE GEOMOUT; with the one of uc pict4_32.mor.

7 How to Get Files

Get pict_w32.exe from the "EGS4 at KEK Web Page".
(<http://ccwww.kek.jp/kek/rad/egs4/egspict.html>).

Extract files on PC by

pict_w32.

The following files are extracted.

- egs4Win32.exe
- info. \$\$\$
- Shower.hlp
- uc pict4_32.mor
- sampl4.dat

References

- [1] H. Hirayama, Y. Namito, S. Ban, R. Ikeda and Y. Tokuda, “EGS4 Shower Display System, EGS4PICT(2), Windows Version”, *KEK Internal 94-10*, National Laboratory for High Energy Physics, (1994).
- [2] H. Hirayama, Y. Namito, S. Ban, R. Ikeda and Y. Tokuda, “EGS4 Shower Display System (EGS4PICT) Windows Version 2.0”, *KEK Internal 96-9*, National Laboratory for High Energy Physics, (1996).
- [3] W. R. Nelson, H. Hirayama and D. W. O. Rogers, “The EGS4 Code System”, *SLAC-265*, Stanford Linear Accelerator Center, (1984).
- [4] W. R. Nelson, private communication (1984).

Appendix: Lists of uc pict4_32.mor

```

!INDENT C6;
!INDENT M3;
!INDENT F2;
"*****"
"***** High Energy Accelerator Research "
"*** U C P I C T 4 _ 3 2** Organization (KEK) "
"***** EGS4 USER CODE -- 31 OCT 2002/1730"
"*****"
"Programmer: H.Hirayama and Y. Namito(KEK) "
"mortjob.pic is used as the trajectory file. "
"EGS4 user's code to output particle trajectory in Fe "
" (ucsampl4.mor with PRESTA) "
"28NOV2001: PLOTXYZ is modified to correct the treatment of "
" discarded particle. "
"26JUL2002: PLOTXYZ is modified not to limit values for X-, Y- or "
" Z-position. "
"31OCT2002: PLOTXYZ is modified to set a particle energy to that of"
" starting point of each line. "
"*****"

"*****"
"*** MAIN ***"
"*****"
"STEP 1. USER-OVER-RIDE-OF-EGS-MACROS"

"PRESTA RELATED"
REPLACE{$CALL-HOWNEAR(#);} WITH
  {$CALL-HOWNEAR-FOR-SLAC-PLANE-GEOMETRY({P1});}
" ***** "
"THIS IS THE MACRO THAT SHOULD RETURN THE CLOSEST PERPENDICULAR "
"DISTANCE TO ANY SURFACE WHICH FORMS A BOUNDARY FOR THE CURRENT REGION."
"IN THIS APPLICATION IT IS REPLACED BY THE MACRO FOLLOWING WHICH IS "
"SPECIALIZED FOR THE SLAC PLANE-GEOMETRY. "
"IT IS THE USER'S RESPONSIBILITY TO PROVIDE THIS MACRO FOR HIS OWN "
"GEOMETRY. "
"++++++"

; "BUFFER FLUSH"
REPLACE{$CALL-HOWNEAR-FOR-SLAC-PLANE-GEOMETRY(#);} WITH
" ====="
  {;ZL=Z(NP); YL=Y(NP); XL=X(NP); IRL=IR(NP);
  ZLEFT=ZL-PCOORD(3,IRL-1); ZRIGHT=PCOORD(3,IRL)-ZL;
  {P1}=MIN(ZLEFT,ZRIGHT);
  YLEFT=YL-PCOORD(2,NPLAN-3); YRIGHT=PCOORD(2,NPLAN-2)-YL;
  {P1}=MIN(YLEFT,YRIGHT,{P1});
  XLEFT=XL-PCOORD(1,NPLAN-1); XRIGHT=PCOORD(1,NPLAN)-XL;
  {P1}=MIN(XLEFT,XRIGHT,{P1});}
"THIS ROUTINE IS INTENDED TO BE USED TO CALCULATE THE MINIMUM "
"PERPENDICLAR TO THE NEAREST BOUNDING SURFACE. THIS VERSION IS "
"SPECIALLY DESIGNED FOR THE SLAC PLANE GEOMETRY PACKAGE. A DIFFERENT "
"VERSION IS NEEDED FOR OTHER GEOMETRY PACKAGES. "

; "BUFFER FLUSH"
"GEOMETRICAL INFORMATION"
"*****"
REPLACE {;COMIN/GEOM/;} WITH {;COMIN/PLADTA/;}
" ====="

REPLACE {;COMIN/PLADTA/;} WITH
" ====="
  {;COMMON/PLADTA/PCOORD(3,$MXPLNS),PNORM(3,$MXPLNS),NPLAN;}

REPLACE {$PRESTA-ON} WITH {0};
"FLAG for PRESTA ON/OFF. 0:PRESTA-ON"
" 1:Default EGS4"

REPLACE{$MXREG} WITH {20} "Over-ride maximum No. of Regions"
;COMIN/BOUNDS,DEBUG,EDGE,ELECIN,MEDIA,MISC,GEOM,THRESH,USEFUL,USER/;

```

```
"COMMONS Need"  
COMMON/LINES/NLINES,NWRITE; "To keep track of lines-printed"  
COMMON/TOTALS/ESUM($MXREG); "For energy conservation check"  
COMMON/PASSIT/NREG;
```

```

COMMON/NFAC/FNORM,XMIN,XMAX,YMIN,YMAX,ZMIN,ZMAX,NPRECI;          "PICT"
$ENERGY PRECISION ESUM,EKIN,TOTKE,ETOT; "Double precision kludge"
" Y.NAMITO & H.HIRAYAMA"
"Create a temporary array and define the MEDIA, next"
$TYPE TEMP(24,2);
DATA TEMP/$S'FE-RAYLEIGH',13*' ',
        $S'AIR AT NTP',14*' '/;
COMIN/RANDOM/; "Locate here to avoid Fortran 77 diagnostic"

"STEP 2. Pre-HATCH-CALL-Initialization"
OPEN(8,FILE='mortjob.dum');
OPEN(12,FILE='sAMPL4.dat',status='old');

NMED=2; "TWO MEDIA WILL BE USED"
DO J=1,NMED [DO I=1,24 [MEDIA(I,J)=TEMP(I,J);]]

"The number of regions---A local variable only"
NREG=6;

MED(1)=0; "Region 1 is vacuum"
MED(2)=2; "Region 2 is Air"
MED(3)=1; "Region 3 is air at NTP"
MED(4)=2; "Region 4 is air at NTP"
MED(5)=0; "Region 5 is vacuum"
MED(6)=0; "Region 6 is vacuum"

"STEP 3. HATCH-CALL"
CALL HATCH;

"STEP 4. Initialization-for-HOWFAR"
ZTHICK=5.0; "SLAB THICKNESS IN CENTIMETERS"
ZAIR=3.0; "Air region in cm"

OPEN(9,file='mortjob.pic',status='unknown');          "PICT"

" Parameter to define graphic size. It is better that the width of each axis is nearly same.
XMIN=-5; XMAX=5.0; YMIN=-5.0; YMAX=5.0;
ZMIN=-2.0; ZMAX=ZTHICK+2.0*ZAIR+2.0;
**PICT**
**PICT**
**PICT**
**PICT**

NPLAN=8;
DO I=1,NPLAN [
DO J=1,3 [
"/PNORM(I,J),PCOORD(I,J)/=0.0;"
/PNORM(J,I),PCOORD(J,I)/=0.0;
]]

/PNORM(3,1),PNORM(3,2),PNORM(3,3),PNORM(3,4)/=1.0;
PCOORD(3,1)=0.0; PCOORD(3,2)=ZAIR;
PCOORD(3,3)=PCOORD(3,2)+ZTHICK;
PCOORD(3,4)=PCOORD(3,3)+ZAIR;

/PNORM(2,5),PNORM(2,6)/=1.0;
PCOORD(2,5)=-5.0; PCOORD(2,6)=5.0;
/PNORM(1,7),PNORM(1,8)/=1.0;
PCOORD(1,7)=-5.0; PCOORD(1,8)=5.0;

CALL GEOMOUT(0,NPLAN);          "**PICT**"

FNORM=AMAX1(XMAX-XMIN,YMAX-YMIN,ZMAX-ZMIN);          "**PICT**"
WRITE(9,:FMT90:) XMIN,XMAX,YMIN,YMAX,ZMIN,ZMAX,FNORM;          "**PICT**"
:FMT90:FORMAT(7E10.3);          "**PICT**"

"STEP 5. Initialization-for-AUSGAB"

"STEP 6. Determination-of-incident-particle-properties"

EKIN=EI+PRM*IQI; "K.E. of particle---PRM is the rest mass"
XI=0.0; YI=0.0; ZI=0.0; "Coordinates of incident particle"

```



```

UI=0.0; VI=0.0; WI=1.0; "Direction cosines---Along Z-axis"
IRI=2; "Incident particle starts out in region 2"
WTI=1.0; "Weight factor---not used in calculation, but"
" is a parameter in SUBROUTINE SHOWER; Hence define"
" as unity"
IXX=987654321; "Random number generator seed"
NCASES=50; "Number of histories (cases) to run"
ICODE=-1; "An output parameter, invented to mark the"
" incident particles"

NPRECI=1; "0:precision of x-, y-, z-position in 4 digits **PICT**"
"1:precision of x-, y-, z-position in 8 digits **PICT**"

"STEP 7. SHOWER-CALL"

III=0;

:NEW-PARTICLE:
OUTPUT;(' Key in Particle type (-1:electron, 0:photon, 1:positron)');
READ(5,*) IQI;

:NEW-ENERGY:
OUTPUT;(' Key in Particle Kinetic Energy in MeV (0.0 means end)');

READ(5,*) EI;
IF(EI.EQ.0.0) GO TO :END OF RUN:;

EKIN=EI;
ECUTMN=ECUT(3); EKO=EKIN; "*PRESTS*"
$PRESTA-INPUTS; "INPUT the *PRESTA* VARIABLES"

IF(IQI.NE.0) [EI=EI+PRM;]

IF(III.NE.0) [
OPEN(9,file='mortjob.pic',ACCESS='APPEND');
]

III=III+1;
WRITE(9,:FMT91:) III; :FMT91:FORMAT('0',I5); "**PICT**"

CALL SHOWER(IQI,EI,XI,YI,ZI,UI,VI,WI,IRI,WTI);

WRITE(9,:FMT92:); :FMT92:FORMAT('9'); "**PICT**"

CALL PLOTXYZ(99,0,0,0.,0.,0.,0.DO); "**PICT**"

CLOSE(UNIT=9, STATUS='KEEP');

OUTPUT;(' Click "Redraw" of EGS4PICT to display trajectories.');
```

GO TO :NEW-PARTICLE:;

"STEP 8. OUTPUT-OF-RESULTS"

```

:END OF RUN:
STOP;
END; "Last statement of main"

%E
SUBROUTINE AUSGAB(IARG);
COMIN/EPCONT,STACK/; "COMMONS NEEDED IN AUSGAB"
COMMON/LINES/NLINES,NWRITE; "TO KEEP TRACK OF LINES-PRINTED"
COMMON/TOTALS/ESUM($MXREG); "FOR ENERGY CONSERVATION CHECK"
$ENERGY PRECISION ESUM; "DOUBLE PRECISION"

CALL PLOTXYZ(IARG,NP,IQ(NP),X(NP),Y(NP),Z(NP),E(NP)); "**PICT**"

RETURN;
END; "LAST STATEMENT OF SUBROUTINE AUSGAB"
```

```

%E
"*****"
"          STANFORD LINEAR ACCELERATOR CENTER"
SUBROUTINE HOWFAR;
"          EGS4 SUBPROGRAM - 8 MAY 1983/1730"
"*****"
;COMIN/DEBUG,EPCONT,GEOM,STACK/;
COMMON/PASSIT/NREG;

IRL=IR(NP); "SET LOCAL VARIABLE"

IF(IRL.LE.1.OR.IRL.GE.NREG-1) [IDISC=1; RETURN;]

NPL1=IRL; NPL2=IRL-1;
NRG1=IRL+1;
NRG2=IRL-1;

$PLAN2P(NPL1,NRG1,1,NPL2,NRG2,-1);

$PLAN2P(6,NREG,1,5,NREG,-1);

$PLAN2P(8,NREG,1,7,NREG,-1);

RETURN;
END; "LAST STATEMENT OF SUBROUTINE HOWFAR"
%E
%E
"*****"
"          KEK, High Energy Accelerator Research Organization "
SUBROUTINE PLOTXYZ(IARG,NP,IQ,X,Y,Z,ENP);
"          EGS4 SUBPROGRAM - 31 Oct 2002/1800"
"  Limitation normalized absolute X-, Y-, or Z- values must be "
"  less than 4.999 is commented out.      26 Jul 2002 H. Hirayama "
"  Revised to include 32 bits version. (NPREC=1) 02 Apr 2001/1100"
"  Revised to include the case that created particle is discarded "
"  immediately.      20 Apr 2001 H. Hirayama "
"19OCT2001: Modified type miss. "
"28NOV2001: Delete unnecessary treatment for the discarded particle"
"31OCT2002: Insert statements to set a particle energy to that of "
"          starting point of each line. "
"*****"
"Output X,Y,Z,IQ,E for 3 dimensional graphic display on PC. "
"This subroutine based on PLOTXZ developed at SLAC for 2 "
"dimensional display with UG. "
"          H. Hirayama "
"*****"
COMIN/DEBUG/;
COMMON/NFAC/FNORM,XMIN,XMAX,YMIN,YMAX,ZMIN,ZMAX,NPRECI; "PICT"
DIMENSION IXPT(100,40),IYPT(100,40),IZPT(100,40),IEPT(100,40),
          NPT(40),IQTOLD(40);
$ENERGYPRECISION ENP;
DATA NPT/40*0/;

IF(IARG.EQ.99) [

DO I=1,40 [
IF(NPT(I).LE.0) NEXT;
IF(IQTOLD(I).EQ.0) [IIQ=1;]
ELSEIF(IQTOLD(I).EQ.-1) [IIQ=2;]
ELSE [IIQ=3;]
IF(NPRECI.NE.0) [IIQ=IIQ+3;]
DO INP=1,NPT(I) [
IF(NPRECI.EQ.0) [
WRITE(9,:FMT9:) IIQ,IXPT(INP,I),IYPT(INP,I),IZPT(INP,I),IEPT(INP,I);
:FMT9:FORMAT(I1,4I5);]
ELSE [
WRITE(9,:FMT90:) IIQ,IXPT(INP,I),IYPT(INP,I),IZPT(INP,I),IEPT(INP,I);
:FMT90:FORMAT(I1,3I8,I5);]

IF(INP.EQ.NPT(I)) [
WRITE(9,:FMT91:);
:FMT91:FORMAT(' -1 ');]
]
]
]

```

```

]
NPT(I)=0;
]

"END OF IARG EQ 99 LOOP"]

ELSE ["IARG NE 99"
"Following limitations are commented out. 7/26/2002 HH"
"IF(X/FNORM.GT.4.999.OR.X/FNORM.LT.-4.999) [RETURN;]
IF(Y/FNORM.GT.4.999.OR.Y/FNORM.LT.-4.999) [RETURN;]
IF(Z/FNORM.GT.4.999.OR.Z/FNORM.LT.-4.999) [RETURN;]"
JARG=IARG;
NPT(NP)=NPT(NP) + 1;
IF(NPT(NP).EQ.1) IQTOLD(NP)=IQ;
IF(NPRECI.EQ.0) [
IXPT(NPT(NP),NP)=X/FNORM*10000+50000;
IYPT(NPT(NP),NP)=Y/FNORM*10000+50000;
IZPT(NPT(NP),NP)=Z/FNORM*10000+50000;
]
ELSE [
IXPT(NPT(NP),NP)=X/FNORM*8388608+33554432;
IYPT(NPT(NP),NP)=Y/FNORM*8388608+33554432;
IZPT(NPT(NP),NP)=Z/FNORM*8388608+33554432;
]

IF(IQ.EQ.0) [EEE=ENP*1000.];]
ELSE [EEE=(ENP-0.511)*1000.]]
IF(EEE.LT.10000.0) [
IEPT(NPT(NP),NP)=INT(EEE)*10;]
ELSE [
IFF=ALOG10(EEE)-3;
IEF=EEE/10**IFF;
IEPT(NPT(NP),NP)=IEF*10+IFF;]

IF(IQ.NE.IQTOLD(NP)) JARG=-1;

IF(NPT(NP).GE.100.OR.JARG.NE.0) [
IF(IQTOLD(NP).EQ.0) [IIQ=1;]
ELSEIF(IQTOLD(NP).EQ.-1) [IIQ=2;]
ELSE [IIQ=3;]
IF(NPRECI.NE.0) [IIQ=IIQ+3;]
IF(NPT(NP).GE.1) [
DO INP=1,NPT(NP) [
IF(NPRECI.EQ.0) [
"Followings are inserted to set a particle energy at that of"
"starting point of each line. 10/31/2002 H.H."
IF(JARG.NE.0.AND.(INP.GT.1.AND.INP.EQ.NPT(NP))) [
WRITE(9,:FMT9:) IIQ,IXPT(INP,NP),IYPT(INP,NP),IZPT(INP,NP),
IEPT(INP-1,NP);]
ELSE [
WRITE(9,:FMT9:) IIQ,IXPT(INP,NP),IYPT(INP,NP),IZPT(INP,NP),
IEPT(INP,NP);]]
ELSE [
"Followings are inserted to set a particle energy at that of"
"starting point of each line. 10/31/2002 H.H."
IF(JARG.NE.0.AND.(INP.GT.1.AND.INP.EQ.NPT(NP))) [
WRITE(9,:FMT90:) IIQ,IXPT(INP,NP),IYPT(INP,NP),IZPT(INP,NP),
IEPT(INP-1,NP);]
ELSE [
WRITE(9,:FMT90:) IIQ,IXPT(INP,NP),IYPT(INP,NP),IZPT(INP,NP),
IEPT(INP,NP);]]
IF(INP.EQ.NPT(NP)) [WRITE(9,:FMT91:);]
]]

IF(JARG.GT.0.OR.IARG.GT.0) [NPT(NP)=0;]

ELSEIF(JARG.EQ.-1) [
IXPT(1,NP)=IXPT(NPT(NP),NP);
IYPT(1,NP)=IYPT(NPT(NP),NP);
IZPT(1,NP)=IZPT(NPT(NP),NP);
IEPT(1,NP)=IEPT(NPT(NP),NP);

```

```

NPT(NP)=1;
IQTOLD(NP)=IQ;
]

ELSE [
NPT(NP)=1;
IXPT(1,NP)=IXPT(100,NP);
IYPT(1,NP)=IYPT(100,NP);
IZPT(1,NP)=IZPT(100,NP);
IEPT(1,NP)=IEPT(100,NP);
]

]

ELSE [IQTOLD(NP)=IQ;]

"END OF IARG NE 99 LOOP"

RETURN;
END; "END OF SUBROUTINE PLOTXYZ"
%E

"*****"
"          KEK, High Energy Accelerator Research Organization"
SUBROUTINE GEOMOUT(NCYLG,NPLANG);
"          EGS4 SUBPROGRAM - 03 MAR 1994/1515"
":FMT93:FORMAT is modified from 8E10.3 to 4E15.7.  21 JUL 2001/0800"
"*****"
"Output geometry data for cylinder-slab or slab geometry.          "
"          H. Hirayama          "
"*****"
COMIN/DEBUG,PLADTA,CYLDTA/;
COMMON/NFAC/FNORM,XMIN,XMAX,YMIN,YMAX,ZMIN,ZMAX,NPRECI;          "PICT"
DIMENSION CYL($MXCYLS),ZBIN($MXPLNS),YBIN($MXPLNS),XBIN($MXPLNS);
IF(NCYLG.NE.0) ["Cylinder slab geometry"
WRITE(9,:FMT90:);
:FMT90:FORMAT('GSTA');
WRITE(9,:FMT91:);
:FMT91:FORMAT('CYLS');

IF(NCYLG.NE.0) ["Cylinder slab geometry"
WRITE(9,:FMT90:);
:FMT90:FORMAT('GSTA');
WRITE(9,:FMT91:);
:FMT91:FORMAT('CYLS');

NZZ=0;
DO I=1,NPLANG [
IF(PNORM(3,I).EQ.1.AND.(PCOORD(3,I).GE.ZMIN.AND.PCOORD(3,I).LE.ZMAX)) [
NZZ=NZZ+1;
ZBIN(NZZ)=PCOORD(3,I);]
]
IF(NZZ.EQ.0) [
NZZ=2;
ZBIN(1)=ZMIN; ZBIN(2)=ZMAX;
]

WRITE(9,:FMT92:) NCYLG,NPLANG;
:FMT92:FORMAT(3I6);
DO I=1,NCYLG [
CYL(I)=SQRT(CYRAD2(I));
]
WRITE(9,:FMT93:) (CYL(I),I=1,NCYLG);
:FMT93:FORMAT(4E15.7);

WRITE(9,:FMT93:) (ZBIN(I),I=1,NZZ);
WRITE(9,:FMT94:);
:FMT94:FORMAT('GEND');
] "End of Cylinder slab geometry"

ELSEIF(NPLANG.NE.0) ["Plane geometry"
WRITE(9,:FMT90:);
WRITE(9,:FMT95:);

```

```

:FMT95:FORMAT('SLAB');

/NZP,NYP,NXP/=0;
DO I=1,NPLANG [
IF(PNORM(1,I).EQ.1) [
IF(PCOORD(1,I).GE.XMIN.AND.PCOORD(1,I).LE.XMAX) [
NXP=NXP+1;
XBIN(NXP)=PCOORD(1,I);]]
ELSEIF(PNORM(2,I).EQ.1) [
IF(PCOORD(2,I).GE.YMIN.AND.PCOORD(2,I).LE.YMAX) [
NYP=NYP+1;
YBIN(NYP)=PCOORD(2,I);]]
ELSE [
IF(PCOORD(3,I).GE.ZMIN.AND.PCOORD(3,I).LE.ZMAX) [
NZP=NZP+1;
ZBIN(NZP)=PCOORD(3,I);]]
]
ZWID=ABS(ZMAX-ZMIN);
IF(NXP.EQ.0) [NXP=2;
XBIN(1)=-ZWID/2.0;
XBIN(2)=ZWID/2.0;]
IF(NYP.EQ.0) [NYP=2;
YBIN(1)=-ZWID/2.0;
YBIN(2)=ZWID/2.0;]
OUTPUT (PNORM(1,I),PNORM(2,I),PNORM(3,I),I=1,NPLANG);
(' PNORM(1) PNORM(2) PNORM(3)')/(3G15.5);
WRITE(9,:FMT92:) NXP,NYP,NZP;
WRITE(9,:FMT93:) (XBIN(I),I=1,NXP);
WRITE(9,:FMT93:) (YBIN(I),I=1,NYP);
WRITE(9,:FMT93:) (ZBIN(I),I=1,NZP);

WRITE(9,:FMT94:);
]
ELSE [" Do not produce geometry data"
WRITE(9,:FMT90:);
WRITE(9,:FMT94:);
STOP;]

RETURN;
END; "END OF SUBROUTINE GEOMOUT"

%E

```

%C80

```
-----"
" Start of PRSTAAUX MORTRAN - Auxiliary codes required by PRESTA. "
"-----" Taken from NRCCAUXP MORTRAN. "
" 24 August 1989 WRN "
"-----"
"
"*****"
" * * "
" * FIXTMX * "
" * * "
" ***** "
SUBROUTINE FIXTMX(ESTEP,MEDIUM);
"
" THIS ROUTINE CHANGES THE STEP SIZE ALGORITHM USED IN EGS SO THAT "
" THE STEP SIZE ARRAYS FOR TMXS CORRESPOND TO AN ARBITRARY,BUT "
" FIXED FRACTIONAL ENERGY LOSS ESTEPE. "
" IT IS ONLY NECESSARY FOR LOW ENERGY ELECTRON PROBLEMS SINCE "
" TYPICALLY THE 200*TEFFO RESTRICTION ON TMXS IS MORE STRINGENT "
" FOR ELECTRONS WITH ENERGIES ABOVE A FEW MEV "
"
" NOTE THAT THE $TMXS-OVER-RIDE MACRO MAY STILL BE IN FORCE IN EGS. "
"
" THE ROUTINE CHANGES THE VALUES ONLY FOR THE MEDIUM 'MEDIUM' "
" AND IT SHOULD PROBABLY BE USED FOR ALL MEDIA IN A PROBLEM. "
"
" THE ROUTINE MUST BE CALLED AFTER HATCH HAS BEEN CALLED AND BEFORE "
" THE SIMULATION IS BEGUN. "
"
" THE ROUTINE IS INDEPENDENT OF WHAT UNITS ARE BEING USED, AS LONG "
" AS THEY ARE CONSISTENT( E.G. CM, RL OR G/CM**2 ) "
"
" IF CALLED WITH IOLDTM=0 (PASSED IN COMIN USER) THE TMXS ARRAYS ARE"
" ADJUSTED TO GIVE A FIXED ESTEPE AND ARE SUBJECTED TO THE TMIN AND "
" CONSTRAINTS. "
" IF CALLED WITH IOLDTM=1 THE CURRENT EGS ALGORITHM IS USED. "
" IF CALLED WITH IOLDTM=0 AND ESTEPE=0 THE CURRENT EGS ALGORITHM IS "
" USED. "
" IF CALLED WITH IOLDTM=1 AND ESTEPE=0 THEN ESTEPE=1.0 IS USED. "
"
" FOR A DETAILED DISCUSSION OF THE USE OF THIS ROUTINE, SEE "
" 'Low Energy Electron Transport with EGS' in Nuclear Instr. and "
" Methods A227 (1984)535-548. D.W.O. Rogers "
"
" FOR A DISCUSSION OF THE NEW FEATURES (V03+) OF THIS ROUTINE, "
" ESPECIALLY WITH REGARD TO THE NEW UPPER AND LOWER LIMITS, SEE "
" 'PRESTA-the Parameter Reduced Electron-Step Transport Algorithm- "
" for Electron Monte Carlo Transport' by A.F.Bielajew & D.W.O.Rogers, "
" NRCC Internal Report PIRS-042 obtainable by contacting the above. "
"
" V01 DEC 10,1981 DAVE ROGERS NRCC "
" V02 DEC 1984 EGS4 VERSION "
" V03 JAN 1986 ALEX BIELAJEW NRCC REVISED FOR PRESTA "
"*****"
;COMIN/ELECI,N,MEDIA,USER/;

ESTEPE=ESTEP;

IF(MEDIUM > $MXMED) ["ERROR" OUTPUT MEDIUM;
(///'0***** MEDIUM=',I4,' IN FIXTMX IS TOO LARGE');RETURN;]
```

```

IF((ESTEPE = 0.) & (IOLDTM = 1)) RETURN; "USE THE CURRENT ALGORITHM "
IF(ESTEPE = 0.) ESTEPE=1.; "NEW VERSION DEFAULTS TO TOTAL ENERGY LOSS"
IF(IOLDTM = 0) [BLCC=BLCC(MEDIUM);XCC2=XCC(MEDIUM)**2; "NEEDED BY ROOTMX"]
"SET UP SOME VARIABLES FOR FIRST PASS THROUGH LOOP"
EI =EXP( (1.-EKEO(MEDIUM))/EKE1(MEDIUM));"ENERGY OF FIRST TABLE ENTRY"

EIL = ALOG(EI); LEIL=1;
"THIS IS EQUIVALENT TO $SETINTERVAL EIL,EKE; BUT AVOIDS ROUNDOFF"
$EVALUATE EDEDX USING EDEDX(EIL);"GET THE ELECTRON STOPPING AT EI"
"NOW CALCULATE STEP REQUIRED TO CAUSE AN ESTEPE REDUCTION IN ENERGY"
IF(IOLDTM = 1) [SI=ESTEPE*EI/EDEDX;]ELSE[SI=ROOTMX(EI,ESTEPE);]
"TABULATED ENERGIES ARE IN A FIXED RATIO - CALC LOG OF THE RATIO"
ERATIO=-1./EKE1(MEDIUM);

NEKE=MEKE(MEDIUM);"NUMBER OF ELEMENTS IN STORAGE ARRAY"
DO I=1,NEKE-1[
EIP1=EXP((FLOAT(I+1)-EKEO(MEDIUM))/EKE1(MEDIUM));"ENERGY AT I+1"
EIP1L=ALOG(EIP1);LEIP1L=I+1;"DESIGNED THIS WAY=$SETINTERVAL"
$EVALUATE EDEDX USING EDEDX(EIP1L);
IF(IOLDTM = 1) [SIP1=ESTEPE*EIP1/EDEDX;]ELSE[SIP1=ROOTMX(EIP1,ESTEPE);]

"NOW SOLVE THESE EQUATIONS                                "
" SI = TMXS1 * EIL + TMXSO                                "
" SIP1 = TMXS1 * EIP1L + TMXSO                            "
"                                                         "
TMXS1(I,MEDIUM)=(SI-SIP1)/ERATIO;TMXSO(I,MEDIUM)=SI-TMXS1(I,MEDIUM)*EIL;

"TRANSFER VALUES FOR NEXT LOOP"
EIL=EIP1L;SI=SIP1;]
"NOW PICK UP LAST TABLE ENTRY WHICH APPLIES ONLY TO LAST ENERGY"
TMXSO(NEKE,MEDIUM)=TMXSO(NEKE-1,MEDIUM);
TMXS1(NEKE,MEDIUM)=TMXS1(NEKE-1,MEDIUM);
RETURN;END;
%E
"*****"
" * * "
" * ROOTMX * "
" * * "
" ***** "
"

FUNCTION ROOTMX(EI,ESTEP);
"
" THIS ROUTINE RETURNS MAX(TMIN,MIN(TMAX,ESTEPE*EI/DEDX)) WHERE "
" TMAX IS THE MAXIMUM STEP ALLOWED BY THE MOLIERE MULTIPLE SCATTERING "
" THEORY, TMIN IS THE THE MINIMUM STEP AND ESTEPE*EI/DEDX IS THE GREATEST "
" STEP ALLOWED DUE TO CONTINUOUS ENERGY LOSS PROCESSES. "
"
" NOTE THE USE OF ITS AUXILLIARY FUNCTION FTMX APPENDED TO ROOTMX. "
" BECAUSE THE TMAX FUNCTION IS STRONGLY ENERGY DEPENDENT, IT WAS FOUND "
" NECESSARY TO INCLUDE A CORRECTION FOR ENERGY LOSS IN IT. OTHERWISE THE "
" UPPER LIMIT COULD BE GREATLY EXCEEDED - BY AS MUCH AS 50% IN SOME CASES. "
" CORRECTING FOR ENERGY LOSS NECESSITATES USING A ROOT FINDING METHOD TO "
" OBTAIN TMAX (HENCE THE NAME ROOTMX). TMIN IS ALSO STRONGLY ENERGY "
" DEPENDENT BUT IT DOES NOT MATTER WITHIN THE LOGIC OF THE CODE IF THIS "
" QUANTITY IS AS MUCH AS 50% HIGH SINCE NO PHYSICS CONSTRAINTS WILL BE "
" VIOLATED. "
"
" THE ZERO-FINDING ROUTINE IS A CRUDE ONE BASED ON THE ASSUMPTION THAT "
" THE FUNCTION FTMX IS MONOTONIC AND THAT THE FUNCTION EVALUATED AT THE TWO "
" STARTING POINTS RETURNS DIFFERENT SIGNS. IF THE SIGNS ARE THE SAME THEN "
" EITHER THE ENERGY-LOSS STEP-SIZE IS MORE RESTRICTIVE OR THE STEP-SIZE IS "
" BELOW TMIN. "
"
" ALTHOUGH THIS ROUTINE COMES WITH THE PRESTA PACKAGE IT IS REALLY "
" INDEPENDENT OF IT AND IT IS AN IMPROVEMENT OVER THE PREVIOUS TMXS METHODS. "
" THE OLD TMXS ROUTINE ALLOWED BOTH THE TMAX AND TMIN BOUNDS TO BE VIOLATED. "
" EXCEEDING TMAX TAKES ONE OUT OF THE REGION OF VALIDITY OF THE MOLIERE "
" THEORY STILL ALLOWING A MULTIPLE SCATTERING SELECTION BUT OF UNPREDICTABLE "
" WORTH. GOING LOWER THAN TMIN CAUSES THE MULTIPLE SCATTERING TO GET "
" SWITCHED OFF (STARTING WITH THE LOWER ENERGIES). THIS CAN SOMETIMES LEAD "
" TO CALCULATIONAL ARTIFACTS. ONE WORD OF CAUTION] USING THIS ROUTINE AT "
" VERY LOW ELECTRON ENERGIES .LE.10 keV CAUSES NEGATIVE USTEP ERRORS IF THE "

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"OLD EGS PATHLENGTH CORRECTION ALGORITHM (BASED ON FERMI-EYGES THEORY) IS "
"USED. THE OLD EGS LESSENERED THIS PROBLEM BY REDUCING THE UPPER LIMIT TO "
"0.8 THE VALUE USED IN THIS ROUTINE. THE PRESTA PATHLENGTH CORRECTION DOES "
"NOT GIVE NEGATIVE USTEPS IN ANY OF THE CASES WE HAVE TESTED. "
" "
"          VERSION 1          ALEX BIELAJEW          JAN. 86 "
"          VERSION 1.1        ALEX BIELAJEW          OCT. 87 "
"                               Lower limit ESTEPE violation fixed "
" "
"*****"
;
COMIN/USEFUL,USER/;
ESTEPE=ESTEP;
TMIN=2.718282*EI*(EI+2.*RM)/(BLCCC*(EI+RM)**2); "LOWER LIMIT, eq.(2-8)"
X1=TMIN; "INITIAL LOWER STARTING POINT OF THE SEARCH"
X2=ESTEPE*EI/EDEX; "INITIAL UPPER STARTING POINT OF THE SEARCH"

"THIS IS THE FIX-UP FOR THE MINIMUM STEP-SIZE"
IF( X2 <= X1 ) [ROOTMX=X1;RETURN;]

F1=FTMX(X1,EI);F2=FTMX(X2,EI);
AF1=ABS(F1);AF2=ABS(F2);
SF1=SIGN(1.,F1);SF2=SIGN(1.,F2);

"FIRST CHECK TO SEE IF EITHER OF THE STARTING POINTS IS ALREADY GOOD ENOUGH."
IF((AF1 <= $ROOTMX_PRECISION) | (AF2 <= $ROOTMX_PRECISION))[
  IF(AF1 <= AF2)[ROOTMX=X1;]ELSE[ROOTMX=X2;]]

"NOW CHECK TO SEE IF EITHER THE ENERGY LOSS IS MORE RESTRICTIVE THAN THE "
"UPPER LIMIT TMAX (TRUE FOR HIGH ENERGIES) OR IF IT MORE RESTRICTIVE THAN "
"TMIN (TRUE FOR LOW ENERGIES WITH A SMALL ENOUGH ESTEPE). "
ELSEIF(SF1 = SF2)[ROOTMX=X2;]

"OTHERWISE A SEARCH FOR TMAX MUST BE UNDERTAKEN."
ELSE[ "ITERATE"
  ITI=0; "NUMBER OF ITERATIONS COUNTER"
  XL=X1; "LAST X FOUND"
  :SEARCH-ROOT:LOOP[
    ITI=ITI+1;
    IF(ITI > 1000)[ "QUIT IF THIS HAPPENS"
      OUTPUT;(' SEARCH FOR TMAX ABORTED. TOO MANY ITERATIONS');STOP;]
    XT=(X1*F2-X2*F1)/(F2-F1);
    IF(XT = XL)[ROOTMX=XT;EXIT:SEARCH-ROOT:;"CONVERGENCE OBTAINED"]
    FT=FTMX(XT,EI);AFT=ABS(FT);
    IF(AFT <= $ROOTMX_PRECISION)[ROOTMX=XT;EXIT:SEARCH-ROOT:;
      "CONVERGENCE OBTAINED"]
    ELSE[ "RE-ITERATE"
      SFT=SIGN(1.,FT);
      IF(SFT = SF1)[X1=XT;F1=FT;AF1=AFT;SF1=SFT;]ELSE[X2=XT;F2=FT;
        AF2=AFT;SF2=SFT;]
      XL=XT; "UPDATE LAST X FOUND"
    ]
  ] "END OF SEARCH FOR ROOT LOOP"
] "END OF ITERATE ELSE"
RETURN;END;

FUNCTION FTMX(T,EI);
"When t=tmax as defined in eq.(2-10) this function returns 0. It is used by"
"FUNCTION ROOTMX in the search for tmax. "
COMIN/USEFUL,USER/;
"Energy dependent quantities are evaluated at the energy mid-point of the "
"step. See section IV of the report PIRS-042. "
EK=AMAX1(0.0001,EI-0.5*EDEX*T);E=EK+RM;BETA2=EK*(E+RM)/E**2;
A=BLCCC/BETA2;G=XCC2/(E*BETA2)**2;
FTMX=1./ALOG(A/G)-G*T;
RETURN;END;

"*****"
"***** End of uc pict4_32.mor *****"
"*****"

```