EGS4 Sample User Codes with PRESTA-CG (ucsampl1cgp.mor and ucsampl2cgp.mor) (October 8, 2002)

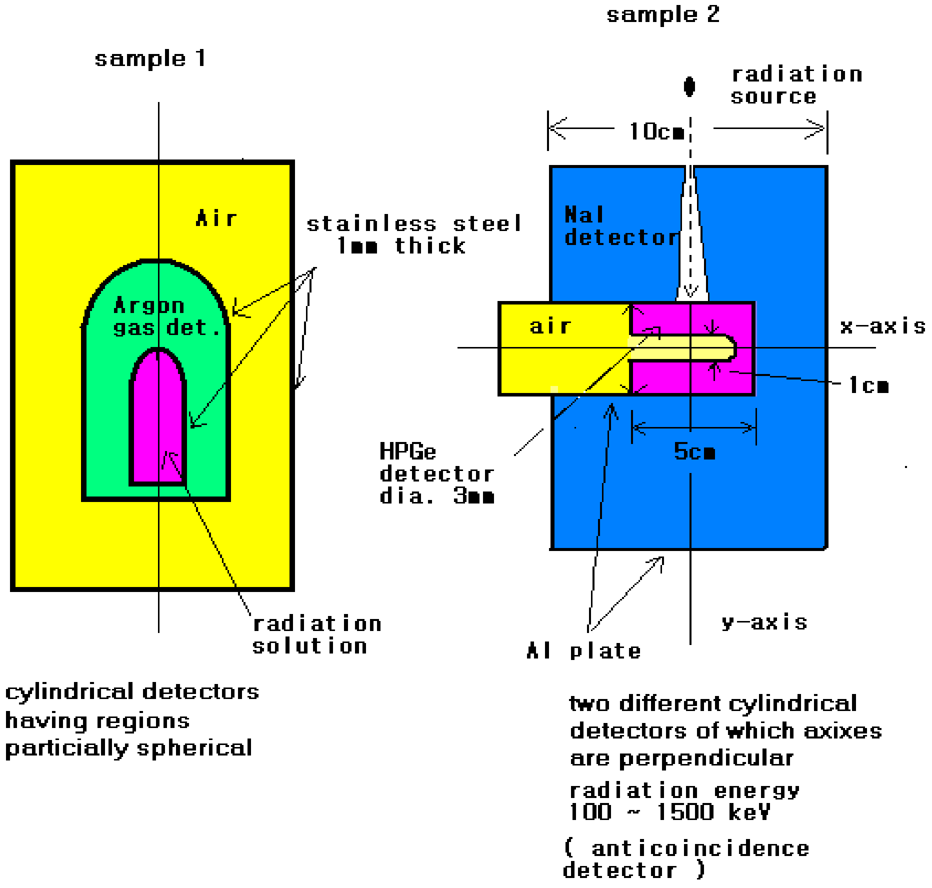
Hideo Hirayama

KEK, High Energy Accelerator Research Organization
1-1, Oho, Tsukuba, Ibaraki, 306-0801 Japan

Contents

1. Outlines of Sample User Code, ucsampl1cgp.mor

Ucsampl1cgp.mor is an user code to simulate an Argon gas detector shown as sample1 in Fig. 1 using PRESTA-CG as the geometry related routines[1]. A Radiation solution is situated at the middle and is surrounded by Argon gas. Both regions are cylindrical geometry having a region partially spherical.



sample 1
Air
Argon gas det.
stainless steel 1mm thick
radiation solution
cylindrical detectors having regions particially spherical
sample 2
radiation source
10cm
NaI detector
air
x-axis
1cm
5cm
HPGe detector dia. 3mm
Al plate
y-axis
two different cylindrical detectors of which axixes are perpendicular
radiation energy 100 ~ 1500 keV
(anticoincidence detector)

Figure 1: Geometry treated in ucsampl1cgp.mor and ucsampl2cgp.mor.

Deposited energies per one source photon at each region are calculated in this user code.

1.1. STEP 1

If a user wishes to modify the macros used in EGS4, put over-ride macros here. Mortran uses the most recent pattern if the same macro pattern is defined differently. The User Code is positioned after various files related to macros used in EGS4. Therefore, if over-ride macros are defined in the User Code, they become effective as the macro definitions. This means that a user can modify EGS4, itself, by using these over-ride macros.

The first macro is the selection of the random number generator. If `RNGEN` is 0, the `RAN6` random number generator is used. If messages of "Same random number will be produced. It is better to use RANNMAR random number generator." appear, it is better to change `RANGEN` to 1 and use `RANMAR` random number generator.

```
REPLACE {$RNGEN} WITH {0}
```

The next one is the selection of Fortran compiler. Set `$COMPILER` to a number corresponding to Fortran compiler used.

It is better to put macros defined by the user in this step. In ucsampl1cgp.mor, `COMMON/TOTALS` (related to score variables), `COMMON/PASSIT` (related to geometry) and `COMMON/LINES` (related to print out intermediate results) are defined as follows.

```
"COMMON to define variables to score at AUSGAB"
"DEPE: deposited energy at each region"

REPLACE {;COMIN/TOTALS/;} WITH
{;COMMON/TOTALS/DEPE($NDET);}

"COMMON of geometry related parameter"

REPLACE {;COMIN/PASSIT/;} WITH
{;COMMON/PASSIT/NREG;}

"COMMON of print-out parameter"

REPLACE {;COMIN/LINES/;} WITH
{;COMMON/LINES/NLINES,NWRITE,NCOUNT,ILINES;}
```

`$PARAMETER` statement define the value of the variables used in the program. If the arguments of the variables are defined by `$PARAMETER` statements, their modification can be done only at `$PARAMETER` statements.

```
PARAMETER $NCASES=5000; "MAXIMUN NUNBER OF CASES"
PARAMETER $NBATCH=50;  "Number of batch"
PARAMETER $MATNO=4;   "Number of material used"
PARAMETER $NDET=6;     "Number of detector"
```

Declarations related to `COMMON` and `DIMENSION` are used in the main program after `PARAMETER` statements. Since `COMMON`s in EGS4 are defined in the form of macros, the `COMMON` parts are expressed as:

```
;COMIN/DEBUG,BOUNDS,BREMPR,EDGE,ELECIN,ETALY1,GEOM,LINES,MEDIA,MISC,
NTALY1,PASSIT,RANDOM,STACK,THRESH,TOTALS,UPHIOT,USEFUL,USER/;
```

`LINES, PASSIT, TOTALS` above the one defined in this user code as mentioned previously.

The next step is defining the material used in the User Code. A material name is defined by 24 characters. The first argument of a `MADARR` must be 24. The second argument is the number of materials used in the User Code and defined by the `PARAMETER` macro.

Although any file names can be assigned for `UNIT 6, 8`, mortjob.xsec (or mortjob.xse in the case of PC) must be assigned as the file name of `UNIT 12` when the user runs the EGS4 program using egs4run etc.

1.2. STEP 2

The variables used in `SUBROUTINE HATCH` must be defined together with the regions shown below. `NMED` is the number of materials used. The information related to the geometry is read from a cg-geometry input file for PRESTA-CG.

```
NMED=$MATNO; "NUMBER OF MEDIA"

DO J=1,NMED [
DO I=1,24 [MEDIA(I,J)=MEDARR(I,J);]]

ITBODY=0;
IRPPIN=0;ISPHIN=0;IRCCIN=0;ITORIN=0;ITRCIN=0;
IZONIN=0;IZONAD=0;
ITVERR=0;
IGMMAX=0;

IFTI = 90;
```

```
IFTO = 6;
CALL GEOMGT(IFTI,IFTO,IGMMAX,ITBODY);

NREG=IZONIN;

MED(NREG)=0;   "VACUUM REGIONS"

MED(1)=1;   "Radiation solution. Water"
MED(2)=4;   "Case of water. Temporary use Fe"
MED(3)=2;   "Ar gas detector"
MED(4)=4;   "Case of detector. Temporary use Fe"
MED(5)=3;   "Air region"
MED(6)=4;   "Case of air. Temporary use Fe"

/IEDGFL(3),IEDGFL(5)/=18;  "18:Atomic number of Ar"
"                 0:K-X ray of Ar is not produced"
```

The material of each region and ECUT, PCUT of each region are defined here. An atomic number to produce fluorescent X-rays is also defined here to each region if it is desired.

AE and AP are used in PEGS4 as the cut-off energy of the material. Electron or positron scattering producing a secondary electron less than AE and bremsstrahlung producing a photon less than AP are included in a continuous slowing down process. If the energy of a particle becomes smaller than ECUT(electron/positron) or PCUT(photon), all kinetic energy of that particle is treated as energy deposition at the point. In the case that ECUT and PCUT is not assigned to each region, AE and AP are assigned as ECUT and PCUT, respectively.

In default EGS4, a compound or mixture material is also treated like an element material. It is not easy to treat X-rays of a compound or mixture generally due to this treatment. One approximate way is to assign the atomic number of the element which is most effective for X-ray production. In this User Code, the atomic number of Ar is used as that of Ar and air (IEDGFL(4)=18;).[*]

1.3. Set Up Options

Various improvements have been made after the release of EGS4. Most of them are in the form of macros, and can be applied by setting up the corresponding flag, like IEDGFL.

The following are introductions for some important flags:

1. Emitting angle of bremsstrahlung[1]
   In the default EGS4, bremsstrahlung is emitted in the direction of the critical angle, $\theta(= m_0/E_0$ radian; m_0, rest mass energy of an electron/positron; E_0,total energy of an electron/positron). If IBRDST=1 is set, the emitted angle is sampled within the critical angle.

   ```
   "THE FOLLOWING REPLACES THE EGS4 DEFAULT $SET-BREMS-ANGLE MACRO   "
   "IT'S USE REQUIRES AN ASSOCIATE MACRO $SET-BREM-REJECTION-FUNCTION"
   "DEFINED BELOW                                                    "
   "                                                                 "
   "USAGE: IBRDST=0 => EGS4 DEFAULT ANGLE SELECTION                  "
   "       IBRDST=1 => KOCH AND MOTZ (1959) EQ. 2BS ANGLE SELECTION  "
   ```

   COMIN/BREMPRR/; must be included at main to use this flag.

2. Emitting angle of an electron and a positron after pair-production[2]
   A similar treatment is applied to pair production in the default EGS4. IPRDST is used to sample the emitting angle more precisely, as shown below:

   ```
   "USAGE: IPRDST=0 => EGS4 DEFAULT ANGLE SELECTION                  "
   "       IPRDST=1 => LOWEST ORDER ANGULAR DISTRIBUTION             "
   ```

[*] It becomes possible to treat X-rays of a compound or mixture generally in KEK extension.

```
"                                                                 "
"          d(Probability)          sin(theta)                     "
"         --------------- = --------------------------------------"
"            d(theta)        2*P[E_total - P*cos(theta)]**2       "
"                                                                 "
"       IPRDST=2 => MOTZ, OLSEN AND KOCH (1969) EQ. 3D-2003       "
"                   IF IPRDST IS NON-ZERO AND E_PHOTON < $BHPAIR  "
"                   THE IPRDST=1 DISTRIBUTION IS USED             "
```

IPRDST is also included in COMIN/BREMPRR/;.

3. Angular distribution of photoelectrons[3]
   A photoelectron is emitted in the direction of the incident photon in the default EGS4. IPHTER must be assigned for each region to apply the angular distribution for photoelectrons.

```
"       IPHTER       REGION DEPENDENT ARRAY FOR SWITCHING ON     "
"                    PHOTOELECTRON ANGULAR DISTRIBUTION          "
"                    DEFAULT(0)-NO SAMPLING, (1)-SAMPLING        "
```

   COMIN/USER/; must be included to use IPHTER in the main program.

4. Bremsstrahlung Splitting[1]
   Bremsstrahlung splitting is a useful variance reduction technique to calculate the contribution of bremsstrahlung in the situation that the bremsstrahlung production probability is small, like in the case of low energy electrons. IBRSPL=1 and NBRSPL must be set to use the bremsstrahlung splitting option.

```
"THIS MACRO PLACES ADDITIONAL BREMSSTRAHLUNG PHOTONS ON THE STACK   "
"RESETTING PARTICLE WEIGHTS TO MAKE THE GAME FAIR. THREE USER INPUTS"
"ARE REQUIRED:                                                      "
"                                                                   "
"IBRSPL = 0 => NO ADDITIONAL BREMSSTRAHLUNG PHOTONS (DEFAULT)       "
"       = 1 => PERFORM BREMSSTRAHLUNG SPLITTING                     "
"NBRSPL = NUMBER OF BREMSSTRAHLUNG PHOTONS CREATED/INTERACTION      "
"FBRSPL = 1/NBRSPL (USED TO ADJUST THE PARTICLE WEIGHTS)           "
"                                                                   "
"NBRSPL AND FBRSPL ARE CHANGED DYNAMICALLY IF STACK OVERFLOW MIGHT  "
"OCCUR                                                              "
"                                                                   "
"THIS MACRO IS INVOKED AFTER THE FIRST CALL THE SUBROUTINE BREMS   "
```

   COMIN/BREMPRR/; must be included to use this option.

1.4. STEP 3

At step 3, SUBROUTINE HATCH is called and material data used in the User Code are read from the material data file. It is better to print out information concerning the materials used (name, density, radiation length, cut-off energy). The name and cut-off energy of each region are also useful to check the program. If the region number is large, it is better to print out only that information necessary to check the material assignment.

The following statement must be included to call SUBROUTINE EDGSET depending the values of IEDGFL:

```
DO I=1,NREG [IF(IEDGFL(I).NE.0) [CALL EDGSET(NREG); EXIT;]]
```

1.5. STEP 4

There is not necessary to write any statements in the case of using PRESTA-CG as the geometry routines. uses Various data related to the geometrical expression are defined at this step

1.6. STEP 5

The initialize variables used in AUSGAB are as follow:

```
CALL ECNSV1(0,NREG,TOTKE);"  INITIALIZE ESUM ARRAY FOR ENERGY"
"                            CONSERVATION CALCULATION."
"                            NREG=NUMBER OF REGIONS"
"                            TOTKE=TOTAL KE (DUMMY VARIABLE HERE)"
"                                  (MUST BE REAL*8)"

CALL NTALLY(0,NREG);

NCOUNT=0;  "PARTICLE HISTORY COUNTER"
ILINES=0;  "INITIALIZE LINE-OUTPUT COUNTER"
DO ND=1,$NDET [
DEPE(ND)=0.D0; "Zero the energy deposition at each region"
]
```

NCOUNT and ILINES are variables used to control the output of intermediate results.

1.7. STEP 6

Define the parameters of the incident particles as follows:

```
IQI=0;  "INCIDENT PARTICLE"

EI=1.33 +ABS(IQI)*PRM;   "TOTAL ENERGY OF PARTICLE (MEV) "

AVAILE=EI + IQI*PRM;  "AVAILABLE K.E. (MEV) (MUST BE REAL*8)"
EKIN=AVAILE;
ECUTMN=ECUT(4); EK0=EKIN;  "*PRESTA*"
$PRESTA-INPUTS;  "INPUT THE *PRESTA* VARIABLES"

XI=0.0; YI=0.0; ZI=0.0;  "STARTING COORDINATES (CM)"
UI=0.0; VI=0.0; WI=1.0;  "INCIDENT DIRECTION COSINES"
RSOURCE=1.9;            "radius of solution"
ZSMIN=6.1; ZSMAX=15.9;  "bottom and top of solution in cm"
ZSSPH=14.0;             "Z-position of center of sphere of solution"

IRI=1;  "ENTRANCE REGION DEFINITION"
WTI=1.0;  "WEIGHT FACTOR OF UNITY"

IDINC=-1; "AN IDENTIFIER (LIKE IARG) TO MARK INCIDENT PARTICLES"

IXXST=17847465;
IXX=IXXST;  "INITIALIZED RANDOM NUMBER WITH STARTING SEED"

$RNG-INITIALIZATION;

NWRITE=10;  "NUMBER OF INCIDENT CASES TO PRINT OUT"

NCASES=$NCASES; "MAXIMUM NUMBER OF INCIDENT CASES TO RUN"
NBATCH=$NBATCH;  "NUMBER OF BATCH"
NCASPB=NCASES/NBATCH; "NUMBER OF CASES PER BATCH"
NOFBAT=0;  "NUMBER OF BATCH FINISHED"

NLINES=15; "NUMBER OF LINES TO PRINT OUT"
```

IQI:type of particle, EI:total energy, XI,YI,ZI:incident position,
UI,VI,WI:direction cosine, IRI:incident region number,
WTI:weight of particle (in ordinary case =1)
RSOURCE, ZSMIN, ZSMAX, ZSSPH:information of the volume source

XI, YI, ZI and UI, VI,WI are re-defined at each history in this user code. ECUTMN=ECUT(4); EK0=EKIN; is defined to initialize PRESTA by the macro $PRESTA-INPUTS.

In addition, the following variables are also defined in this step:

`IDINC=-1`:variable to indicate the incident particle,
`IXXST`:initial seed of random number,
output condition of intermediate results,
`NCASES`:history number,
`NBATCH`:batch number if the calculation is divided into batch,
`NCASPB`:history number per batch

1.8. STEP 7

This step is the main part of the User Code calling `SUBROUTINE SHOWER` `NCASES`-times.

In this user code, positions and direction cosines must be determined each time as follows:

```
:POSITION:
$RANDOMSET XI0; XI0=2.0*XI0-1.0;
$RANDOMSET YI0; YI0=2.0*YI0-1.0;
IF(XI0*XI0+YI0*YI0.GT.1.0) GO TO :POSITION:;
XI=XI0*RSOURCE; YI=YI0*RSOURCE;
$RANDOMSET ZI0;
ZI=ZSMIN+ZI0*(ZSMAX-ZSMIN);
IF(ZI.GT.ZSSPH) [
ZZZ=ZI-ZSSPH;
RR=SQRT(XI*XI+YI*YI+ZZZ*ZZZ);
IF(RR.GT.RSOURCE) GO TO :POSITION:;
]

:DIRECTION-COSINE:
$RANDOMSET UI0;
XI0=2.0*UI0-1.0;
$RANDOMSET VI0;
YI0=2.0*VI0-1.0;
$RANDOMSET WI0;
ZI0=2.0*WI0-1.0;
RRR=SQRT(XI0*XI0+YI0*YI0+ZI0*ZI0);
IF(RRR.GT.1.0) GO TO :DIRECTION-COSINE:;
UI=XI0/RRR;  VI=YI0/RRR;  WI=ZI0/RRR;
```

1.8.1. Statistical analysis: Assume that x is a quantity we calculate during the course of a Monte Carlo calculation, *i.e.* a scoring variable. The output of a Monte Carlo calculation is usually useless unless we can ascribe a probability error to it. There are 2 conventional approaches to calculating the probable error.

1.8.1..1 Method used in MCNP:

- Assume that the calculation calls for N "incident" particle histories.
- Assume that x_i is the result at the i-th history.
- Calculate the mean value of x :

$$\overline{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \tag{1}$$

- Estimate the variance associated with the distribution of x_i:

$$s^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2 \simeq \overline{x^2} - (\overline{x})^2 \quad (\overline{x^2} = \frac{1}{N}\sum_{i=1}^{N} x_i^2). \tag{2}$$

- Estimate the variance associated with the distribution of $\overline{x}$:

$$s_{\overline{x}}^2 = \frac{1}{N}s^2 \simeq \frac{1}{N}[\overline{x^2} - (\overline{x})^2] \tag{3}$$

- Report the statistical error as:

$$R = s_{\overline{x}}/\overline{x} \simeq [\frac{1}{N}(\frac{\overline{x^2}}{\overline{x}^2} - 1)]^{1/2} \tag{4}$$

1.8.1..2 Method used in MORSE-CG:

- Assume that the calculation calls for N "incident" particle histories.
- Split the "N" histories into n statistical batches of N/n histories each. The calculated quantity for each of these batches is called x_i.
- Calculate the mean value of x:

$$\overline{x} = \frac{1}{N}\sum_{i=1}^{n} x_i \tag{5}$$

- Estimate the variance associate with the distribution of the x_i:

$$s_x^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i^2 - \overline{x}^2) \tag{6}$$

- The estimated variance of $\overline{x}$ is the standard variance of the mean:

$$s_{\overline{x}}^2 = \frac{s_x^2}{n} \tag{7}$$

- Report FSD(fractional standard deviation) as the statistical error:

$$\text{FSD} = s_{\overline{x}}/\overline{x} \tag{8}$$

1.8.1..3 Treatments in ucsampl1cgp.mor for a statistical analysis: ucsampl1cgp.mor calculates `FSD` based on the method used in `MORCE-CG`. The histories(`NCASES`) are divided into `NBATCH` statistical batches of `NCASPB(=NCASES/NBATCH)` histories each.

The mean value $\overline{x}$ is calculated after the end of each batch.

```
"Calculate average value for this BATCH"

DO ND=1,$NDET [
DEPEPB(ND,NOFBAT)=DEPE(ND)/NCASPB; "Energy deposition for this BATCH"
DEPE(ND)=0.0;
]
```

1.9. STEP 8

Analyze the obtained results and output them in this step. It is also better to print out the information about the geometry and source particle.

Calculate the average values and their deviations (x_i) from the results per batch.

In this User Code, the deposited energy at each region are presented in MeV per source photon.

```
"Calculate average and its deviation"

OUTPUT ;(/' Energy deposition at each region ');
DO ID=1,$NDET [

/AVDE,DESCI2/=0.0;
DO J=1,NBATCH [
AVDE=AVDE+DEPEPB(ID,J)/NBATCH;
DESCI2=DESCI2+DEPEPB(ID,J)*DEPEPB(ID,J)/NBATCH;
]
SIGPH=SQRT((DESCI2-AVDE*AVDE)/(NBATCH-1));
OUTPUT ID,(MEDIA(II,MED(ID)),II=1,24);
(' At region ',I3,'(',24A1,')');
OUTPUT AVDE,SIGPH;
('   Energy deposition =',G15.5,'+-',G15.5,
' MeV/source'/);
]

"NEXT, CALL THE SUBROUTINE ECNSV1 TO WRITE-OUT THE ENERGY DEPOSITION"
"TOTALS---TO CHECK ENERGY CONSERVATION FOR ONE THING"

CALL ECNSV1(1,NREG,TOTKE);

CALL NTALLY(1,NREG);
```

Statements to output the statistical results obtained by subroutines ECNSV1 or NTALLY are included in this user code.

1.10. SUBROUTINE AUSGAB

AUSGAB is a subroutine used to score the information that user wants to calculate. In ucsampl1cgp.mor, the energy deposition at each region is scored as follows:

```
IF(IRL.NE.NREG) ["particle is inside the material"
DEPE(IRL)=DEPE(IRL)+EDEP;  "Add energy deposition"
] "end of inside material"
```

1.11. SUBROUTINE HOWFAR

The function of HOWFAR is to provide information to EGS about the nature of the geometry.

HOWFAR must determine if USTEP will carry the particle past the boundary that the particle is heading towards. If so, then:

1. USTEP must be shrunk to the distance to the boundary, and
2. IRNEW must be set the "new" region in which the particle will end up.

The PRESTA-CG uses its own HOWFAR included in cghowfar.mor.

1.12. Geometry input data for ucsampl1cgp.mor

6 cylinders and 2 spheres are defines as bodies and each region is defined using defined bodies as follows:

```
  RCC     1 0.0        0.0        0.0        0.0        0.0      30.0
           10.0
  RCC     2 0.0        0.0        0.1        0.0        0.0      29.8
            9.9
  RCC     3 0.0        0.0        5.0        0.0        0.0      15.0
            5.0
  RCC     4 0.0        0.0        5.1        0.0        0.0      14.9
            4.9
  RCC     5 0.0        0.0        6.0        0.0        0.0       8.0
            2.0
  RCC     6 0.0        0.0        6.1        0.0        0.0       7.9
            1.9
  SPH     7 0.0        0.0       14.0        1.9
  SPH     8 0.0        0.0       14.0        2.0
  SPH     9 0.0        0.0       20.0        4.9
  SPH    10 0.0        0.0       20.0        5.0
  RCC    11 0.0        0.0       -1.0        0.0        0.0      40.0
           15.0
  END
  Z1            +6 OR +7
  Z2            +5 -6 OR +8 -7 -5
  Z3            +4 -5 -8 OR +9 -4
  Z4            +3 -4 OR +10 -9 -3
  Z5            +2 -3 -10
  Z6            +1 -2
  Z7            +11 -1
  END
```

2. Outlines of Sample User Code, ucsampl2cgp.mor

Ucsampl2cgp.mor is an user code to simulate a Ge detector response surrounding NaI detector as an anticoincidence detector shown as sample2 in Fig. 1 using PRESTA-CG as the geometry related routines[1]. Two different cylindrical detectors of which axes are perpendicular. Point isotropic source is put at the center of a collimator having a truncated cone shape.

The energy depositions in the Ge and NaI detectors are scored for each source photon. The pulse-height distribution of the Ge detector and that of anticoincidence with the NaI detector is scored using the energy deposition at each detector.

The most parts of this user code are similar with ucsampl1cgp.mor. The different parts at each step are shown at the following subsections.

2.1. STEP 1

```
"COMMON to define variables to score at AUSGAB"
"DEPE1:deposited energy inside the detector 1"
"DEPE2:deposited energy inside the detector 2"
"DELTAE:energy bin width in MeV"

REPLACE {;COMIN/TOTALS/;} WITH
{;COMMON/TOTALS/DEPE1,DEPE2,DELTAE;}


PARAMETER $NCASES=5000; "MAXIMUN NUNBER OF CASES"
PARAMETER $MATNO=3;     "Number of material used"
PARAMETER $NBATCH=50;   "Number of batch"
PARAMETER $NEBIN=50;    "Number of energy bin"
```

2.2. STEP 2

```
NMED=$MATNO; "NUMBER OF MEDIA"

DO J=1,NMED [
DO I=1,24 [MEDIA(I,J)=MEDARR(I,J);]]

ITBODY=0;
IRPPIN=0;ISPHIN=0;IRCCIN=0;ITORIN=0;ITRCIN=0;
IZONIN=0;IZONAD=0;
ITVERR=0;
IGMMAX=0;

IFTI = 90;
IFTO = 6;
CALL GEOMGT(IFTI,IFTO,IGMMAX,ITBODY);


NREG=IZONIN;

MED(NREG)=0;   "VACUUM REGIONS"

MED(1)=1;   "Ge detector"
MED(2)=3;   "Air region"
MED(3)=2;   "NAI"
MED(4)=3;   "Collimator region"

/ECUT(1),ECUT(3)/=0.561;

IEDGFL(1)=32;  "53:Atomic number of Ge"
"                0:X ray of Ge is not produced"
IEDGFL(3)=53;  "53:Atomic number of I"
"                0:X ray of I is not produced"
```

2.3. STEP 5

The initialize variables used in AUSGAB are as follow:

```
/DEPE1,DEPE2/=0.D0; "ZERO THE ENERGY DEPOSITION AT SCINTILATOR"
/PEF,TEF/=0.0;  "Zero the efficiency"

DO J=1,$NEBIN [/PH1(J),PH2(J),PHA(J)/=0.0;]  "Zero the pulse-height"
```

DEPE1, DEPE2: Deposited energy at Ge and NaI detector, respectively.
PEF, TFE: Peak and total efficiencies of Ge detector without anticoincidence mode.
PH1, PH2, PHA: Pulse height distribution of Ge, NaI and Ge with anticoincidence.

2.4. STEP 6

```
DELTAE=0.05;  "Energy bin of response"

XI=0.0; YI=0.0; ZI=6.5;  "STARTING COORDINATES (CM)"
UI=0.0; VI=0.0; WI=1.0;  "INCIDENT DIRECTION COSINES"
SDTE=1.0;                "Source detector distance in cm"
RADNAI=5.0;              "Radius of NaI detector in cm"
RRR=SQRT(SDTE*SDTE+RADNAI*RADNAI);
WIMAX=-SDTE/RRR;         "Maximum WI value"
```

SDTE: distance between a source position and a collimator entrance,
RADNAI: radius of the NaI detector,
WIMAX: maximum values of cosθ to enter the detector system.

2.5. STEP 7

In this user code, the direction cosines are determined at first. After that, the source X- and Y- position at the detector surface and the corresponding region number are calculated.

```
"Determine directional cosine"
$RANDOMSET WI0;
WI=(WIMAX+1.0)*WI0-1.0;
$RANDOMSET PHAI0;
PHAI=PI*(2.0*PHAI0-1.0);
SINTH=SQRT(1.0-WI*WI);
UI=COS(PHAI)*SINTH;
VI=SIN(PHAI)*SINTH;

"Calculate incident X and Y position and region"
DIST=SDTE/WI;
XI=SDTE*UI;
YI=SDTE*VI;
RRR=SQRT(XI*XI+YI*YI);
IF(RRR.LE.0.25) [IRI=4;  "Inside collimator"]
ELSE [IRI=3;  "Incident on NaI"]
```

When each history ends, pulse height distributions are scored depending the deposited energy at the Ge and NaI detector.

```
"If some energy is deposited inside detector add pulse-height"
"and efficiency"

IF(DEPE1.GT.0.D0) [
IE=DEPE1/DELTAE+1;
IF(IE.LE.$NEBIN) [PH1(IE)=PH1(IE)+WTI;]
IF(DEPE1.GE.EI*0.999) [PEF=PEF+WTI;]
IF(DEPE2.EQ.0.0) [
"No energy deposition at detector 2"
PHA(IE)=PHA(IE)+WTI;
]
TEF=TEF+WTI;]
IF(DEPE2.GT.0.D0) [
IE=DEPE2/DELTAE+1;
IF(IE.LE.$NEBIN) [PH2(IE)=PH2(IE)+WTI;]
]

/DEPE1,DEPE2/=0.D0;
```

2.6. STEP 8

```
"Calculate average and its deviation"

/AVPE,DESCI2/=0.0;
DO J=1,NBATCH [
AVPE=AVPE+PEFPB(J)/NBATCH;
DESCI2=DESCI2+PEFPB(J)*PEFPB(J)/NBATCH;
]
SIGPE=SQRT((DESCI2-AVPE*AVPE)/(NBATCH-1));
AVPE=AVPE*100.0;
SIGPE=SIGPE*100.0;
OUTPUT AVPE,SIGPE;(' Peak efficiency =',G15.5,'+-',G15.5,' %');

/AVTE,DESCI2/=0.0;
DO J=1,NBATCH [
AVTE=AVTE+TEFPB(J)/NBATCH;
DESCI2=DESCI2+TEFPB(J)*TEFPB(J)/NBATCH;
]
SIGTE=SQRT((DESCI2-AVTE*AVTE)/(NBATCH-1));
AVTE=AVTE*100.0;
SIGTE=SIGTE*100.0;
OUTPUT AVTE,SIGTE;(' Total efficiency =',G15.5,'+-',G15.5,' %');

OUTPUT ;(/' Pulse height distribution of detector 1');
DO IE=1,$NEBIN [
ELOW=DELTAE*(IE-1);
EUP=DELTAE*IE;
IF(ELOW.GT.EKIN) [EXIT;]

/AVPH,DESCI2/=0.0;
DO J=1,NBATCH [
AVPH=AVPH+PH1PB(IE,J)/NBATCH;
DESCI2=DESCI2+PH1PB(IE,J)*PH1PB(IE,J)/NBATCH;
]
SIGPH=SQRT((DESCI2-AVPH*AVPH)/(NBATCH-1));
OUTPUT EUP,AVPH,SIGPH;
(' E (upper-edge --',G10.4,' MeV )=',G15.5,'+-',G15.5,
' counts/bin/incident');
]

OUTPUT ;(//' Pulse height distribution of detector 2');
DO IE=1,$NEBIN [
ELOW=DELTAE*(IE-1);
EUP=DELTAE*IE;
IF(ELOW.GT.EKIN) [EXIT;]

/AVPH,DESCI2/=0.0;
DO J=1,NBATCH [
AVPH=AVPH+PH2PB(IE,J)/NBATCH;
DESCI2=DESCI2+PH2PB(IE,J)*PH2PB(IE,J)/NBATCH;
]
SIGPH=SQRT((DESCI2-AVPH*AVPH)/(NBATCH-1));
OUTPUT EUP,AVPH,SIGPH;
(' E (upper-edge --',G10.4,' MeV )=',G15.5,'+-',G15.5,
' counts/bin/incident');
]

OUTPUT ;
(//' Pulse height distribution of detector 1 with anti-coincidence');
DO IE=1,$NEBIN [
ELOW=DELTAE*(IE-1);
EUP=DELTAE*IE;
IF(ELOW.GT.EKIN) [EXIT;]

/AVPH,DESCI2/=0.0;
DO J=1,NBATCH [
AVPH=AVPH+PHAPB(IE,J)/NBATCH;
DESCI2=DESCI2+PHAPB(IE,J)*PHAPB(IE,J)/NBATCH;
]
SIGPH=SQRT((DESCI2-AVPH*AVPH)/(NBATCH-1));
OUTPUT EUP,AVPH,SIGPH;
(' E (upper-edge --',G10.4,' MeV )=',G15.5,'+-',G15.5,
' counts/bin/incident');
]
```

2.7. SUBROUTINE AUSGAB

AUSGAB is a subroutine used to score the information that user wants to calculate. In ucsampl2cgp.mor, the energy deposition at Ge or NaI region is scored as follows:

```
IF(MED(IRL).EQ.1) ["particle is inside the detector 1"
DEPE1=DEPE1+EDEP;  "Add energy deposition"]

IF(MED(IRL).EQ.2) ["particle is inside the detector 2"
DEPE2=DEPE2+EDEP;  "Add energy deposition"]
```

2.8. Geometry input data for ucsampl1cgp.mor

5 cylinders, 1 sphere and 1 truncated cone are defines as bodies and each region is defined using defined bodies as follows:

```
  RCC    1 0.00      0.0      -6.50        0.00      0.0     13.00
           5.00
  RCC    2 -2.5      0.0        0.0        5.00      0.0      0.0
           1.50
  RCC    3 -6.0      0.0        0.0        8.5       0.0     0.0
           1.5
  RCC    4 -2.5      0.0        0.0        3.5       0.0     0.0
           0.5
  SPH    5  1.0      0.0        0.0        0.5
  TRC    6 0.00      0.0        0.0        0.00      0.0     6.5
           1.15      0.5
  RCC    7 0.00      0.0      -15.0        0.00      0.0     30.0
           8.00
  END
  Z1           +2   -4   -5
  Z2           +3   -2  OR   +4  OR   +5
  Z3           +1   -3   -6
  Z4           +6   -3
  Z4           +7   -1   -3
  END
```

References

[1] T. Torii and T. Sugita, ‘‘Development of PRESTA-CG Incorprating Combinatorial Geometry in EGS4/PRESTA", *JNC TN1410 2002-201*, Japan Nuclear Cycle Development Institute (2002).

Appendix 1 Full listings of ucsampl1cgp.mor

```
!INDENT M3;
!INDENT F2;
"******************************************************************"
"***************************  High Energy Accelerator Research    *"
"***************************  Organization, KEK                   *"
"***  U C S A P L 1 C G P **                                      *"
"***************************  EGS4 USER CODE -- 16 JAN 2001/0930  *"
"******************************************************************"
"                                                                  "
"  PROGRAMMER:   Hideo Hirayama                                    "
"                KEK, High Energy Accelerator Research Organization"
"                1-1, Oho, Tsukuba, Ibaraki, 305-0801 Japan        "
"                                                                  "
"******************************************************************"
"                                                                  "
"  PROGRAM:      ucsampl1cgp                                       "
"                                                                  "
"                EGS4 user code for sampl1 problem requested by    "
"                Gwang Ho Yoo.  Use PRESTA-CG geometry.            "
"                Add Ranmar random generator option.               "
"                                                                  "
"******************************************************************"
"                                                                  "
"                     F E A T U R E S                              "
"                                                                  "
"    - USES ENERGY CONSERVATION PROGRAM CALLED ECNSV1              "
"    - USES 'COUNTER' ROUTINE CALLED NTALLY                        "
"                                                                  "
"******************************************************************"
"                                                                  "
"       THE FOLLOWING 'STEPS' REFER TO THE STEPS OUTLINED          "
"       IN THE EGS3 USER MANUAL (SLAC-210).                        "
"       VARIOUS EGS USER NOTES (EUN'S) HAVE BEEN CREATED           "
"       TO SUPPLEMENT SLAC-210 FOR THE CORRECTIONS, CHANGES        "
"       AND ADDITIONS THAT ARE IN EGS4.                            "
"                                                                  "
"******************************************************************"
"******** STEP 1.  USER-OVER-RIDE-OF-EGS-MACROS *******************"
"******************************************************************"
%C80
!NEWCONDITIONAL;
"------------------------------------------------------------------"
"Select random number generator: 0=RAN6 1=RANMAR                  "
"RANMAR is a Lagged-Fibonacci Method pseudo random number generator"
"devised by George Marsaglia and Arif Zaman.                       "
"------------------------------------------------------------------"
REPLACE {$RNGEN} WITH {0}

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

REPLACE {;COMIN/RANDOM/;} WITH {
 {SETR B=$RNGEN}
 [IF] {COPY B}=0 [
   ;COMMON/RANDOMM/URNDM(97),IXX,IXXST;
   ]
 [IF] {COPY B}=1 [
   "This is ranmar.correlations (SID 1.8 last edited 18 Dec 1996)"
   " by Alex F Bielajew                                          "
   "RANDOM VARIABLE COMMON"
   "RANDMO, RANNDM1, RANDM2 ARE SHADOW AREAS USED FOR CORRELATIONS"
   ;COMMON/RANDOMM/URNDM(97),CRNDM,CDRNDM,CMRNDM,IXX,JXX,IDUM2   ;
   COMMON/RANDM0/UDM0(97), CDM0, CDDM0, CMDM0, IXXDM0,JXXDM0;
   COMMON/RANDM1/UDM1(97), CDM1, CDDM1, CMDM1, IXXDM1,JXXDM1;
   COMMON/RANDM2/UDM2(97), CDM2, CDDM2, CMDM2, IXXDM2,JXXDM2;
   REAL URNDM,CRNDM,CDRNDM,CMRNDM,UDM0,CDM0,CDDM0,CMDM0,UDM1,CDM1,
   CDDM1,CMDM1,UDM2,CDM2,CDDM2,CMDM2, r4opt;
   INTEGER IXX,JXX,IDUM2,IXXDM0,JXXDM0,IXXDM1,JXXDM1,IXXDM2,JXXDM2,
   IXXIN,JXXIN;
   ]
 }

REPLACE {$RANDOMSET#;} WITH {
 {SETR B=$RNGEN}
 [IF] {COPY B}=0 [
   IXX=IXX*663608941;{P1}=IXX*0.23283064E-09;IF(IXX.LT.0){P1}={P1}+1.0;
   IF(IXX.EQ.IXXST) [OUTPUT;(' WARNING !'/
   ' Same random number will be produced.'/
   ' It is better to use RANNMAR random number generator.')]
   ]
 [IF] {COPY B}=1 [
    {P1}=URNDM(IXX)-URNDM(JXX); IF({P1}.LT.0.) {P1}={P1}+1.;
    URNDM(IXX) = {P1};
    IXX=IXX-1; IF(IXX.EQ.0) IXX=97;
    JXX=JXX-1; IF(JXX.EQ.0) JXX=97;
    CRNDM=CRNDM-CDRNDM; IF(CRNDM.LT.0.) CRNDM=CRNDM+CMRNDM;
    {P1}={P1}-CRNDM; IF({P1}.LT.0.) {P1}={P1}+1.;
   ]
   }

"This should be called somewhere near the beginning of the main routine"
"before any random numbers are asked for";
REPLACE {$RNG-INITIALIZATION;} WITH {;
 {SETR B=$RNGEN}
 [IF] {COPY B}=0 [;]
 [IF] {COPY B}=1 [ IXX=0; JXX=0; CALL RMARIN;
      DO II=1,20005[
      $RANDOMSET XRANM;
      IF(II.GT.20000) OUTPUT (MOD(INT(XRANM*16.**JJ),16),JJ=1,7);
      (8X,7I3); ]
    ]
 }

"-------------ranmar.correlations---------------"
"This is ranmar.correlations (SID 1.8 last edited 18 Dec 1996)"
%C80
;
"**********************************************************************"
"                                                                      "
"                  ranmar.correlations                                 "
"                  *******************                                 "
"                                                                      "
"  Macro set for doing restarts and correlations                       "
"                                                                      "
"  Coding for the EGS4 system by:                                      "
"                                                                      "
"  Alex F Bielajew  89/12/21  Version 1.0                              "
"  Institute for National Measurement Standards                        "
"  National Research Council of Canada                                 "
"  Ottawa, CANADA                                                      "
"  KIA 0R6                                                             "
"                                                                      "
" 95/11/15  changed STORE-RNG  so -re argument does not cause bomb DR  "
"            also exlicitly included types in RANDOM                   "
"                                                                      "
" 96/08/09  added r4opt to random def'n and in RANDOMSET   DR          "
"                                                                      "
" 96/12/18  Removed redundant declaration of                           "
"           $RANDOMSET                                                 "
"           $COMMON-RANDOM-DECLARATION-IN-BLOCK-DAT                    "
"           and                                                        "
"           $RNG-INITIALIZATION                                        "
"           Only home for  these is in ranmar.macros - BLIF            "
"                                                                      "
"**********************************************************************"
;
REPLACE {$STORE-RNG(#);} WITH {
;IDUM2 = {P1};
;IF(IDUM2.EQ.0)[
      DO IDUM=1,97[UDM0(IDUM)=URNDM(IDUM);]
      CDM0=CRNDM;CDDM0=CDRNDM;CMDM0=CMRNDM;IXXDM0=IXX;JXXDM0=JXX;
      ]
  ELSEIF(IDUM2.EQ.-1)[
      DO IDUM=1,97[UDM1(IDUM)=URNDM(IDUM);]
      CDM1=CRNDM;CDDM1=CDRNDM;CMDM1=CMRNDM;IXXDM1=IXX;JXXDM1=JXX;
      ]
  ELSEIF(IDUM2.EQ.-2)[
      DO I=1,97[UDM2(IDUM)=URNDM(IDUM);]
      CDM2=CRNDM;CDDM2=CDRNDM;CMDM2=CMRNDM;IXXDM2=IXX;JXXDM2=JXX;
      ]
  ELSE[
      WRITE(IDUM2,*)URNDM,CRNDM,CDRNDM,CMRNDM,IXX,JXX;
      ]
}
 ;
REPLACE {$RESET-RNG(#);} WITH {
;IDUM2 = {P1};
;IF(IDUM2.EQ.0)[
      DO IDUM=1,97[URNDM(IDUM)=UDM0(IDUM);]
      CRNDM=CDM0;CDRNDM=CDDM0;CMRNDM=CMDM0;IXX=IXXDM0;JXX=JXXDM0;
      ]
  ELSEIF(IDUM2.EQ.-1)[
      DO IDUM=1,97[URNDM(IDUM)=UDM1(IDUM);]
      CRNDM=CDM1;CDRNDM=CDDM1;CMRNDM=CMDM1;IXX=IXXDM1;JXX=JXXDM1;
      ]
  ELSEIF(IDUM2.EQ.-2)[
      DO IDUM=1,97[URNDM(IDUM)=UDM2(IDUM);]
      CRNDM=CDM2;CDRNDM=CDDM2;CMRNDM=CMDM2;IXX=IXXDM2;JXX=JXXDM2;
      ]
  ELSE[
      READ(IDUM2,*)URNDM,CRNDM,CDRNDM,CMRNDM,IXX,JXX;
      ]
}

;
"-------------end of ranmar.correlations---------------"

"------------------------------------------------------------------"
"      PLACE COMPILER DEPENDENT SUBROUTINE CALL HERE               "
"------------------------------------------------------------------"
" Select Fortran Compiler.                                         "
" Lahey Fortran = 1                                                "
" Microsoft Fortran = 2                                            "
" Other PC = 3 (default)                                           "
" g77 on Windows  = 4                                              "
" Sun UNIX Workstation and Linux = 5                               "
" Other UNIX Workstation =6                                        "
"------------------------------------------------------------------"
REPLACE {$COMPILER} WITH {4}
"------------------------------------------------------------------"

"------------------------------------------------------------------"
"Macro to select the timer to be used (compiler dependent).        "
"------------------------------------------------------------------"
REPLACE {$TIMERSET;} WITH {;}

REPLACE {$TIME-NOW#;} WITH {
  {SETR B=$COMPILER}
  [IF] {COPY B}=1 [CALL TIMER({P1});]
  [IF] {COPY B}=2 [CALL GETTIM(IHR,IMIN,ISEC,I100);
                  {P1}=(IHR*3600+IMIN*60+ISEC)*100+I100;]
  [IF] {COPY B}=3 [{P1}=0.0;]
  [IF] {COPY B}=4 [TT=ETIME(TARRAY);
                  {P1}=TARRAY(1)*100.0;]
  [IF] {COPY B}=5 [TT=ETIME(TARRAY);
                  {P1}=TARRAY(1)*100.0;]
  [IF] {COPY B}=6 [{P1}=0.0;]
}

"------------------------------------------------------------------"
"Macro to define DIMENSION related to the timer to be used         "
"                                    (compiler dependent).         "
"------------------------------------------------------------------"
REPLACE {$TIME-DIM;} WITH {
  {SETR B=$COMPILER}
  [IF] {COPY B}=1 [;]
  [IF] {COPY B}=2 [;]
  [IF] {COPY B}=3 [;]
  [IF] {COPY B}=4 [REAL TARRAY(2);]
  [IF] {COPY B}=5 [REAL TARRAY(2);]
  [IF] {COPY B}=6 [;]
}

"------------------------------------------------------------------"
"Macro to define DIMENSION related to the timer to be used         "
"                                    (compiler dependent).         "
"------------------------------------------------------------------"
REPLACE {$TIME-DIM;} WITH {
  {SETR B=$COMPILER}
  [IF] {COPY B}=4 [REAL TARRAY(2);]
  [ELSE]          [;]
}

"------------------------------------------------------------------"
"Macro to define OPEN STATEMENT for Cross-section data.            "
"                                            (UNIX or PC).         "
"------------------------------------------------------------------"

REPLACE {$OPEN;} WITH {
  {SETR B=$COMPILER}
  [IF] {COPY B}<5 [OPEN(12,FILE='mortjob.xse',status='old');
                   OPEN(6,FILE='mortjob.out',status='unknown');
                   OPEN(8,FILE='mortjob.dum',status='unknown');
                   OPEN(UNIT=90,FILE='USER.F90',STATUS='UNKNOWN');]
  [ELSE]          [OPEN(12,FILE='mortjob.xsec',status='old');
```

```
                   OPEN(6,FILE='mortjob.output',status='unknown');
                   OPEN(8,FILE='mortjob.dummy',status='unknown');
                   OPEN(UNIT=90,FILE='USER.F90',STATUS='UNKNOWN');]
}

"COMMON to define variables to score at AUSGAB"
"DEPE:deposited energy at each region"

REPLACE {;COMIN/TOTALS/;} WITH
{;COMMON/TOTALS/DEPE($NDET);}

"COMMON of geometry related parameter"

REPLACE {;COMIN/PASSIT/;} WITH
{;COMMON/PASSIT/NREG;}

"COMMON of print-out parameter"

REPLACE {;COMIN/LINES/;} WITH
{;COMMON/LINES/NLINES,NWRITE,NCOUNT,ILINES;}

PARAMETER $NCASES=5000; "MAXIMUN NUNBER OF CASES"
PARAMETER $NBATCH=50;  "Number of batch"
PARAMETER $MATNO=4;   "Number of material used"
PARAMETER $NDET=6;     "Number of detector"

"******************************************************************"
"******************* ADDITIONAL (NON-EGS) MACROS ******************"
"******************************************************************"

"                      N O N E                                     "

"******************************************************************"
"************************** DECLARATIONS **************************"
"******************************************************************"

;COMIN/DEBUG,BOUNDS,BREMPR,EDGE,ELECIN,ETALY1,GEOM,LINES,MEDIA,MISC,
NTALY1,PASSIT,RANDOM,STACK,THRESH,TOTALS,UPHIOT,USEFUL,USER/;
DIMENSION DEPEPB($NDET,$NBATCH);
REAL*8 TOTKE,AVAILE,DEPE;
       "NEEDED FOR ENERGY CONSERVATION TABULATION"

$TYPE   MEDARR(24,$MATNO);
DATA MEDARR/$S'WATER-IAPRIM',12*' ',
            $S'AR-GAS-IAPRIM',11*' ',
            $S'AIR-IAPRIM',14*' ',
            $S'FE-IAPRIM',15*' '/;


"******************************************************************"
"*************** START OF EXECUTABLE CODE *************************"
"******************************************************************"

$OPEN;

"******************************************************************"
"******** STEP 2.  PRE-HATCH-CALL-INITIALIZATION COMES NEXT *******"
"******************************************************************"
NMED=$MATNO; "NUMBER OF MEDIA"

DO J=1,NMED [
DO I=1,24 [MEDIA(I,J)=MEDARR(I,J);]]

ITBODY=0;
IRPPIN=0;ISPHIN=0;IRCCIN=0;ITORIN=0;ITRCIN=0;
IZONIN=0;IZONAD=0;
ITVERR=0;
IGMMAX=0;

IFTI = 90;
IFTO = 6;
CALL GEOMGT(IFTI,IFTO,IGMMAX,ITBODY);


NREG=IZONIN;

MED(NREG)=0;   "VACUUM REGIONS"

MED(1)=1;   "Radiation solution. Water"
MED(2)=4;   "Case of water. Temporary use Fe"
MED(3)=2;   "Ar gas detector"
MED(4)=4;   "Case of detector. Temporary use Fe"
MED(5)=3;   "Air region"
MED(6)=4;   "Case of air. Temporary use Fe"

/IEDGFL(3),IEDGFL(5)/=18;  "18:Atomic number of Ar"
"                0:K-X ray of Ar is not produced"

"******************************************************************"
"***************** STEP 3.  HATCH-CALL COMES NEXT *****************"
"******************************************************************"

CALL HATCH;

"OUTPUT VARIOUS QUANTITIES ASSOCIATED WITH THE MEDIA"

OUTPUT;  ('1QUANTITIES ASSOCIATED WITH EACH MEDIA:',//);

DO J=1,NMED [
OUTPUT (MEDIA(I,J),I=1,24);  (/,1X,24A1);
OUTPUT RHO(J),RLC(J);  (5X,' RHO=',G15.7,' G/CM**3     RLC=',
   G15.7,' CM');
OUTPUT AE(J),UE(J);  (5X,' AE=',G15.7,' MEV    UE=',G15.7,' MEV');
OUTPUT AP(J),UP(J);  (5X,' AP=',G15.7,' MEV    UP=',G15.7,' MEV');
]

OUTPUT;(/' INFORMATION OF MEDIUM AND CUT-OFFFOR EACH REGION'//);
DO I=1,NREG [
IF(MED(I).EQ.0) [OUTPUT I,ECUT(I),PCUT(I);
(' MEDIUM(',I3,')=VACUUM',18X,'ECUT=',G10.5,' MEV, PCUT=',G10.5,' MEV');
]
ELSE [OUTPUT I,(MEDIA(II,MED(I)),II=1,24),ECUT(I),PCUT(I);
(' MEDIUM(',I3,')=',24A1,'ECUT=',G10.5,' MEV, PCUT=',G10.5,' MEV');]
]

DO I=1,NREG [IF(IEDGFL(I).NE.0) [CALL EDGSET(NREG); EXIT;]]

"******************************************************************"
"*********** STEP 4.  HOWFAR-INITIALIZATION COMES NEXT ************"
"******************************************************************"

"******************************************************************"
"********** STEP 5.  INITIALIZATION FOR AUSGAB COMES NEXT *********"
"******************************************************************"

CALL ECNSV1(0,NREG,TOTKE);"  INITIALIZE ESUM ARRAY FOR ENERGY"
"                            CONSERVATION CALCULATION."
"                            NREG=NUMBER OF REGIONS"
"                            TOTKE=TOTAL KE (DUMMY VARIABLE HERE)"
"                                  (MUST BE REAL*8)"

CALL NTALLY(0,NREG);

NCOUNT=0;  "PARTICLE HISTORY COUNTER"
ILINES=0;  "INITIALIZE LINE-OUTPUT COUNTER"
DO ND=1,$NDET [
DEPE(ND)=0.D0; "Zero the energy deposition at each region"
]

"******************************************************************"
"****** STEP 6.  DETERMINATION OF INCIDENT PARTICLE PROPERTIES ****"
"******************************************************************"

IQI=0;  "INCIDENT PARTICLE"

EI=1.33 +ABS(IQI)*PRM;   "TOTAL ENERGY OF PARTICLE (MEV) "

AVAILE=EI + IQI*PRM;  "AVAILABLE K.E. (MEV) (MUST BE REAL*8)"
EKIN=AVAILE;
ECUTMN=ECUT(4); EKO=EKIN;  "*PRESTA*"
$PRESTA-INPUTS;  "INPUT THE *PRESTA* VARIABLES"

XI=0.0; YI=0.0; ZI=0.0;  "STARTING COORDINATES (CM)"
UI=0.0; VI=0.0; WI=1.0;  "INCIDENT DIRECTION COSINES"
RSOURCE=1.9;            "radius of solution"
ZSMIN=6.1; ZSMAX=15.9;  "bottom and top of solution in cm"
ZSSPH=14.0;             "Z-position of center of sphere of solution"

IRI=1;  "ENTRANCE REGION DEFINITION"
WTI=1.0;  "WEIGHT FACTOR OF UNITY"

IDINC=-1; "AN IDENTIFIER (LIKE IARG) TO MARK INCIDENT PARTICLES"
```

```
IXXST=17847465;
IXX=IXXST;  "INITIALIZED RANDOM NUMBER WITH STARTING SEED"

$RNG-INITIALIZATION;

NWRITE=10;  "NUMBER OF INCIDENT CASES TO PRINT OUT"

NCASES=$NCASES; "MAXIMUM NUMBER OF INCIDENT CASES TO RUN"
NBATCH=$NBATCH;  "NUMBER OF BATCH"
NCASPB=NCASES/NBATCH; "NUMBER OF CASES PER BATCH"
NOFBAT=0;  "NUMBER OF BATCH FINISHED"

NLINES=15; "NUMBER OF LINES TO PRINT OUT"


"******************************************************************"
"******************* STEP 7. SHOWER-CALL---NEXT ******************"
"******************************************************************"

DO NOFBAT=1,NBATCH [ "BATCH-LOOP"

DO I=1,NCASPB ["START OF SHOWER CALL LOOP OF EACH BATCH"

:POSITION:
$RANDOMSET XI0; XI0=2.0*XI0-1.0;
$RANDOMSET YI0; YI0=2.0*YI0-1.0;
IF(XI0*XI0+YI0*YI0.GT.1.0) GO TO :POSITION:;
XI=XI0*RSOURCE; YI=YI0*RSOURCE;
$RANDOMSET ZI0;
ZI=ZSMIN+ZI0*(ZSMAX-ZSMIN);
IF(ZI.GT.ZSSPH) [
ZZZ=ZI-ZSSPH;
RR=SQRT(XI*XI+YI*YI+ZZZ*ZZZ);
IF(RR.GT.RSOURCE) GO TO :POSITION:;
]

:DIRECTION-COSINE:
$RANDOMSET UI0;
XI0=2.0*UI0-1.0;
$RANDOMSET VI0;
YI0=2.0*VI0-1.0;
$RANDOMSET WI0;
ZI0=2.0*WI0-1.0;
RRR=SQRT(XI0*XI0+YI0*YI0+ZI0*ZI0);
IF(RRR.GT.1.0) GO TO :DIRECTION-COSINE:;
UI=XI0/RRR;  VI=YI0/RRR;  WI=ZI0/RRR;

IF(NCOUNT.LE.NWRITE.AND.ILINES.LE.NLINES) [
  OUTPUT EI,XI,YI,ZI,UI,VI,WI,
  IQI,IRI,IDINC;   (7G15.7,3I5);
  ILINES=ILINES+1;]

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

NCOUNT=NCOUNT + 1;
IXXEND=IXX;   "LAST RANDOM NUMBER USED"

] "End of SHOWER CALL loop for each BATCH"

"Calculate average value for this BATCH"

DO ND=1,$NDET [
DEPEPB(ND,NOFBAT)=DEPE(ND)/NCASPB; "Energy deposition for this BATCH"
DEPE(ND)=0.0;
]

]  "End of BATCH-loop"

TOTKE=NCOUNT*AVAILE; "TOTAL (AVAILABLE) K.E."

"******************************************************************"
"******************* STEP 8. OUTPUT OF RESULTS ******************"
"******************************************************************"

OUTPUT NCOUNT,IXXST,IXXEND,AVAILE,TOTKE;
('1',I10,' CASES COMPLETED',
     /,' IXXST=',I12,/,' IXXEND=',I12,/,' AVAILABLE K.E.=',
     G15.5,' MEV',/,' TOTKE=',E15.5,' MEV');

OUTPUT;(/' PRESTA algorithm is used'/);

"Calculate average and its deviation"
```

```
OUTPUT ;(/' Energy deposition at each region ');
DO ID=1,$NDET [

/AVDE,DESCI2/=0.0;
DO J=1,NBATCH [
AVDE=AVDE+DEPEPB(ID,J)/NBATCH;
DESCI2=DESCI2+DEPEPB(ID,J)*DEPEPB(ID,J)/NBATCH;
]
SIGPH=SQRT((DESCI2-AVDE*AVDE)/(NBATCH-1));
OUTPUT ID,(MEDIA(II,MED(ID)),II=1,24);
(' At region ',I3,'(',24A1,')');
OUTPUT AVDE,SIGPH;
('   Energy deposition =',G15.5,'+-',G15.5,
' MeV/source'/);
]

"NEXT, CALL THE SUBROUTINE ECNSV1 TO WRITE-OUT THE ENERGY DEPOSITION"
"TOTALS---TO CHECK ENERGY CONSERVATION FOR ONE THING"

CALL ECNSV1(1,NREG,TOTKE);

CALL NTALLY(1,NREG);

STOP;
END;  "END OF MAIN PROGRAM"

%E
"******************************************************************"
"                                 STANFORD LINEAR ACCELERATOR CENTER"
SUBROUTINE AUSGAB(IARG);
"                                 EGS4 SUBPROGRAM -  8 MAY 1983/1730"
"******************************************************************"
;COMIN/DEBUG,EPCONT,ETALY1,LINES,MISC,NTALY1,PASSIT,STACK,TOTALS,USEFUL/;
REAL*8 DPWT,DEPE;
IRL=IR(NP);   "SET LOCAL VARIABLE"
DPWT=WT(NP);

"KEEP TRACK OF THE ENERGY DEPOSITION---FOR CONSERVATION PURPOSES"
ESUM(IQ(NP)+2,IRL,IARG+1)=ESUM(IQ(NP)+2,IRL,IARG+1)+EDEP*DPWT;
NSUM(IQ(NP)+2,IRL,IARG+1)=NSUM(IQ(NP)+2,IRL,IARG+1) + 1;

IF(IRL.NE.NREG) ["particle is inside the material"
DEPE(IRL)=DEPE(IRL)+EDEP;  "Add energy deposition"
] "end of inside material"

IF(NCOUNT.LE.NWRITE.AND.ILINES.LE.NLINES) [
OUTPUT E(NP),X(NP),Y(NP),Z(NP),U(NP),V(NP),W(NP),
  IQ(NP),IRL,IARG;   (7G15.7,3I5);
ILINES=ILINES+1;]

RETURN;
END;  "END OF SUBROUTINE AUSGAB"

%E

"******************************************************************"
"                                 STANFORD LINEAR ACCELERATOR CENTER"
SUBROUTINE ECNSV1(NTREE,NREG,TOTKE);
"                                 EGS4 SUBPROGRAM - 20 JUN 1983/1445"
"******************************************************************"
"   SUBROUTINE FOR KEEPING TRACK OF ENERGY CONSERVATION---TO BE    "
"   USED WITH EGS USER CODES.  WHEN NTREE=0, THE PROGRAM IS        "
"   ENTERED IN ORDER TO INITIALIZE THE ESUM ARRAY TO ZERO.         "
"   OTHERWISE, IT IS ENTERED FOR TOTALING AND OUTPUTTING THE       "
"   RESULTS.  THE ESUM ARRAY IS NEEDED IN SUBROUTINE AUSGAB,       "
"   WHERE EDEP (ENERGY DEPOSITION) IS ADDED TO THE ELEMENT OF      "
"   THE ARRAY CORRESPONDING TO THE VALUE OF IQ, IR, AND IARG.      "
"******************************************************************"
COMIN/DEBUG,ETALY1/;  "INSERT IN ALL SUBPROGRAMS THAT USE ESUM"
REAL*8 ROWSUM(4,$MXREG),COLSUM(4,5),SUMSUM(4),GSUM,TOTKE;

"   CHECK WHETHER NREG IS GE $MXREG.  IF IT IS, STOP AND OUTPUT.   "
IF(NREG.GT.$MXREG) [
MDUMMY=$MXREG;
OUTPUT NREG,MDUMMY;
(///,' ***** NOTE: STOPPED IN SUBROUTINE ECNSV1 BECAUSE NREG= ',
 I5,' IS LARGER THAN $MXREG= ',I5,' *****');
STOP;]

IF(NTREE.EQ.0) [                "INITIALIZE ESUM TO ZERO AND RETURN"
```

```
  DO I=1,4 [
    DO J=1,NREG [
      DO K=1,5 [ESUM(I,J,K)=0.D0;]
    ]
  ]
RETURN;]

"   REACH THIS POINT WHEN FINAL TALLY IS TO BE MADE."

"   FIRST, INITIALIZE SUMS"

GSUM=0.D0;

DO IQ=1,4 [
SUMSUM(IQ)=0.D0;
DO IR=1,NREG [ROWSUM(IQ,IR)=0.D0;]
DO ICODE=1,5 [COLSUM(IQ,ICODE)=0.D0;]
"   END OF IQ-LOOP"]

"   SUM IQ=1,2,3 INTO IQ=4 OF ESUM FOR ALL IR- AND ICODE-VALUES"

DO IR=1,NREG [
DO ICODE=1,5 [
DO IQ=1,3 [
ESUM(4,IR,ICODE)=ESUM(4,IR,ICODE) + ESUM(IQ,IR,ICODE);
]]]

"   NORMALIZE DATA TO TOTKE"

DO IQ=1,4 [
DO IR=1,NREG [
DO ICODE=1,5 [
IF(TOTKE.NE.0.D0) [ESUM(IQ,IR,ICODE)=ESUM(IQ,IR,ICODE)/TOTKE;]
]]]

"   SUM-UP COLUMNS AND ROWS"

DO IQ=1,4 [
DO IR=1,NREG [
DO ICODE=1,5 [
ROWSUM(IQ,IR)=ROWSUM(IQ,IR)+ESUM(IQ,IR,ICODE);
]]

DO ICODE=1,5 [
DO IR=1,NREG [
COLSUM(IQ,ICODE)=COLSUM(IQ,ICODE)+ESUM(IQ,IR,ICODE);
]]
"   END OF IQ-LOOP"]

"   NOW GET TOTAL FOR IQ AND GRAND TOTAL"

DO IQ=1,4 [
DO IR=1,NREG [
DO ICODE=1,5 [
SUMSUM(IQ)=SUMSUM(IQ)+ESUM(IQ,IR,ICODE);
IF(IQ.LE.3) [GSUM=GSUM+ESUM(IQ,IR,ICODE);]
]]]


"   NOW WRITE-OUT THE RESULTS OF THE ENERGY DEPOSITION SUMMARY"

DO IQ=1,4 [
IF(IQ.LE.3) [
IQNOW=IQ-2;
OUTPUT IQNOW;
(///' ENERGY DEPOSITION SUMMARY FOR PARTICLES WITH IQ=',I2,///,
55X,'IARG',/,19X,'0',15X,'1',13X,'2',14X,'3',14X,'4',16X,'ROW SUM',
/,3X,'REGION',/);
]
ELSE [
OUTPUT;  (' ENERGY DEPOSITION SUMMARY FOR ALL PARTICLES:',///,
55X,'IARG',/,19X,'0',15X,'1',13X,'2',14X,'3',14X,'4',16X,'ROW SUM',
/,3X,'REGION',/);
]

DO IR=1,NREG [
OUTPUT IR,(ESUM(IQ,IR,ICODE),ICODE=1,5),ROWSUM(IQ,IR);
  (I7,5X,5G15.7,5X,G15.7);
"   END OF IR-LOOP"]

OUTPUT (COLSUM(IQ,ICODE),ICODE=1,5),SUMSUM(IQ);
(/,3X,'COL SUM',2X,5G15.7,5X,G15.7);
```

```
"   END OF IQ-LOOP"]

OUTPUT GSUM; (/////,' TOTAL FRACTION=',G15.7,
'     NOTE: THIS NUMBER SHOULD BE VERY CLOSE TO UNITY');


RETURN;
END;  "END OF SUBROUTINE ECNSV1"

%E
"******************************************************************"
"                                STANFORD LINEAR ACCELERATOR CENTER"
SUBROUTINE NTALLY(NTREE,NREG);
"                                EGS4 SUBPROGRAM - 20 JUN 1983/1445"
"******************************************************************"
"   THIS PROGRAM KEEPS 'TALLY' OF THE NUMBER OF TIMES AUSGAB IS    "
"   ENTERED FOR VARIOUS REASONS, ETC.  IT GIVES THE USER A 'ROUGH' "
"   IDEA OF WHETHER CERTAIN EVENTS ARE RARE OR NOT.                "
"   CAUTION *** DO NOT USE THESE NUMBERS IN ANY STATISTICAL SENSE! "
"******************************************************************"
COMIN/DEBUG,NTALY1/;
INTEGER ROWSUM(4,$MXREG),COLSUM(4,5),SUMSUM(4),GSUM;

"   CHECK WHETHER NREG IS GE $MXREG.  IF IT IS, STOP AND OUTPUT."
IF(NREG.GT.$MXREG) [
MDUMMY=$MXREG;
OUTPUT NREG,MDUMMY;
(///,' ***** NOTE: STOPPED IN SUBROUTINE NTALLY BECAUSE NREG= ',
 I5,' IS LARGER THAN $MXREG= ',I5,' *****');
STOP;]

IF(NTREE.EQ.0) [  "INITIALIZE NSUM TO ZERO AND RETURN"
DO I=1,4 [DO J=1,NREG [DO K=1,5 [NSUM(I,J,K)=0;]]]
RETURN;]

"   REACH THIS POINT WHEN FINAL TALLY IS TO BE MADE."

"   FIRST, INITIALIZE SUMS"

GSUM=0;

DO IQ=1,4 [
SUMSUM(IQ)=0;
DO IR=1,NREG [ROWSUM(IQ,IR)=0;]
DO ICODE=1,5 [COLSUM(IQ,ICODE)=0;]
"   END OF IQ-LOOP"]

"   SUM IQ=1,2,3 INTO IQ=4 OF NSUM FOR ALL IR- AND ICODE-VALUES"

DO IR=1,NREG [
DO ICODE=1,5 [
DO IQ=1,3 [
NSUM(4,IR,ICODE)=NSUM(4,IR,ICODE) + NSUM(IQ,IR,ICODE);
]]]

"   SUM-UP COLUMNS AND ROWS"

DO IQ=1,4 [
DO IR=1,NREG [
DO ICODE=1,5 [
ROWSUM(IQ,IR)=ROWSUM(IQ,IR)+NSUM(IQ,IR,ICODE);
]]

DO ICODE=1,5 [
DO IR=1,NREG [
COLSUM(IQ,ICODE)=COLSUM(IQ,ICODE)+NSUM(IQ,IR,ICODE);
]]
"   END OF IQ-LOOP"]

"   NOW GET TOTAL FOR IQ AND GRAND TOTAL"

DO IQ=1,4 [
DO IR=1,NREG [
DO ICODE=1,5 [
SUMSUM(IQ)=SUMSUM(IQ)+NSUM(IQ,IR,ICODE);
IF(IQ.LE.3) [GSUM=GSUM+NSUM(IQ,IR,ICODE);]
]]]


"   NOW WRITE-OUT THE RESULTS"
```

```
DO IQ=1,4 [
IF(IQ.LE.3) [
IQNOW=IQ-2;
OUTPUT IQNOW;
(///' SUMMARY OF EVENT COUNT FOR PARTICLES WITH IQ=',I2,///,
55X,'IARG',/,19X,'0',15X,'1',13X,'2',14X,'3',14X,'4',16X,'ROW SUM',
/,3X,'REGION',/);
]
ELSE [
OUTPUT;  (' SUMMARY OF EVENT COUNT FOR ALL PARTICLES:',///,
55X,'IARG',/,19X,'0',15X,'1',13X,'2',14X,'3',14X,'4',16X,'ROW SUM',
/,3X,'REGION',/);
]

DO IR=1,NREG [
OUTPUT IR,(NSUM(IQ,IR,ICODE),ICODE=1,5),ROWSUM(IQ,IR);
  (I7,5X,5I15,5X,I15);
"   END OF IR-LOOP"]

OUTPUT (COLSUM(IQ,ICODE),ICODE=1,5),SUMSUM(IQ);
(/,3X,'COL SUM',2X,5I15,5X,I15);

"   END OF IQ-LOOP"]

OUTPUT GSUM; (/////,' TOTAL NUMBER OF EVENTS=',I15);


RETURN;
END;  "END OF SUBROUTINE NTALLY"

%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*TEFF0 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 (PASSSED 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/ELECIN,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)[BLCCC=BLCC(MEDIUM);XCC2=XCC(MEDIUM)**2; "NEEDED BY ROOTMX"]
"SET UP SOME VARIABLES FOR FIRST PASS THROUGH LOOP"
EI =EXP( (1.-EKE0(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 STOPPPING 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)-EKE0(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   + TMXS0                                 "
"  SIP1 = TMXS1 * EIP1L + TMXS0                                 "
"                                                               "
TMXS1(I,MEDIUM)=(SI-SIP1)/ERATIO;TMXS0(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"
TMXS0(NEKE,MEDIUM)=TMXS0(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 MINIMUN 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 "
"    OLD EGS PATHLENGTH CORRECTION ALGORITHM (BASED ON FERMI-EYGES THEORY) IS  "
"    USED. THE OLD EGS LESSENED 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/EDEDX; "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 TMXS 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*EDEDX*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;
%E

"*****************************************************************"
SUBROUTINE RMARIN;
"*****************************************************************"
COMIN/RANDOM/;

IF((IXX.LE.0).OR.(IXX.GT.31328)) IXX=1802; "SETS MARSAGLIA DEFAULT"

" BUG. In the following line the assignment previous to 90/09/18  "
" was to IXX. This DID NOT upset the randomness of the sequence,  "
" just the initial starting point. BLIF 90/09/18.                 "

IF((JXX.LE.0).OR.(JXX.GT.30081)) JXX=9373; "SETS MARSAGLIA DEFAULT"

I = MOD(IXX/177,177) + 2;
J = MOD(IXX,    177) + 2;
K = MOD(JXX/169,178) + 1;
```

```
L = MOD(JXX,    169)    ;

DO II=1,97[
    S=0.0;T=0.5;
    DO JJ=1,24[
        M=MOD(MOD(I*J,179)*K,179);
        I=J;J=K;K=M;L=MOD(53*L+1,169);
        IF(MOD(L*M,64).GE.32) S=S+T;
        T=0.5*T;
        ]
    URNDM(II)=S;
    ]

CRNDM  =   362436./16777216.;
CDRNDM =  7654321./16777216.;
CMRNDM = 16777213./16777216.;

IXX = 97;
JXX = 33;

RETURN;END;

"******************************************************************"
"*********************** ucsampl1cgp end **************************"
"******************************************************************"
%N
```

Appendix 2 Full listings of ucsampl2cgp.mor

The parts after SUBROUTINE ECNSV1 are same with ucsampl1cgp.mor and are not shown.

```
!INDENT M3;
!INDENT F2;
%L
"******************************************************************"
"***************************  High Energy Accelerator Research    *"
"***************************  Organization, KEK                   *"
"*** U C S A M P L 2 C G P *                                      *"
"***************************  EGS4 USER CODE -- 30 AUG 2002/0930  *"
"******************************************************************"
"                                                                  "
"  PROGRAMMER:   Hideo Hirayama                                    "
"                KEK, High Energy Accelerator Research Organization"
"                1-1, Oho, Tsukuba, Ibaraki, 305-0801 Japan        "
"                                                                  "
"******************************************************************"
"                                                                  "
"  PROGRAM:      UCSAMPL2CGP                                       "
"                                                                  "
"                EGS4 user code to calculate Ge response with/     "
"                without coincidence to outside NaI.               "
"                Two different cylindrical detectors of which      "
"                axis are perpendicular.                           "
"                Add Ranmar random generator option.               "
"                                                                  "
"******************************************************************"
"                                                                  "
"                     F E A T U R E S                              "
"                                                                  "
"    - USES ENERGY CONSERVATION PROGRAM CALLED ECNSV1              "
"    - USES 'COUNTER' ROUTINE CALLED NTALLY                        "
"                                                                  "
"******************************************************************"
"                                                                  "
"       THE FOLLOWING 'STEPS' REFER TO THE STEPS OUTLINED          "
"       IN THE EGS3 USER MANUAL (SLAC-210).                        "
"       VARIOUS EGS USER NOTES (EUN'S) HAVE BEEN CREATED           "
"       TO SUPPLEMENT SLAC-210 FOR THE CORRECTIONS, CHANGES        "
"       AND ADDITIONS THAT ARE IN EGS4.                            "
"                                                                  "
"******************************************************************"
"******** STEP 1.  USER-OVER-RIDE-OF-EGS-MACROS *******************"
"******************************************************************"
%C80
!NEWCONDITIONAL;
"------------------------------------------------------------------"
"Select random number generator: 0=RAN6 1=RANMAR                   "
"RANMAR is a Lagged-Fibonacci Method pseudo random number generator"
"devised by George Marsaglia and Arif Zaman.                       "
"------------------------------------------------------------------"
REPLACE {$RNGEN} WITH {0}

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

REPLACE {;COMIN/RANDOM/;} WITH {
 {SETR B=$RNGEN}
 [IF] {COPY B}=0 [
   ;COMMON/RANDOMM/URNDM(97),IXX,IXXST;
   ]
 [IF] {COPY B}=1 [
   "This is ranmar.correlations (SID 1.8 last edited 18 Dec 1996)"
   " by Alex F Bielajew                                           "
   "RANDOM VARIABLE COMMON"
   "RANDMO, RANNDM1, RANDM2 ARE SHADOW AREAS USED FOR CORRELATIONS"
   ;COMMON/RANDOMM/URNDM(97),CRNDM,CDRNDM,CMRNDM,IXX,JXX,IDUM2   ;
   COMMON/RANDM0/UDM0(97), CDM0, CDDM0, CMDM0, IXXDM0,JXXDM0;
   COMMON/RANDM1/UDM1(97), CDM1, CDDM1, CMDM1, IXXDM1,JXXDM1;
   COMMON/RANDM2/UDM2(97), CDM2, CDDM2, CMDM2, IXXDM2,JXXDM2;
   REAL URNDM,CRNDM,CDRNDM,CMRNDM,UDM0,CDM0,CDDM0,CMDM0,UDM1,CDM1,
   CDDM1,CMDM1,UDM2,CDM2,CDDM2,CMDM2, r4opt;
   INTEGER IXX,JXX,IDUM2,IXXDM0,JXXDM0,IXXDM1,JXXDM1,IXXDM2,JXXDM2,
   IXXIN,JXXIN;
   ]
 }

REPLACE {$RANDOMSET#;} WITH {
 {SETR B=$RNGEN}
 [IF] {COPY B}=0 [
   IXX=IXX*663608941;{P1}=IXX*0.23283064E-09;IF(IXX.LT.0){P1}={P1}+1.0;
   IF(IXX.EQ.IXXST) [OUTPUT;(' WARNING !'/
   ' Same random number will be produced.'/
   ' It is better to use RANNMAR random number generator.')]
   ]
 [IF] {COPY B}=1 [
    {P1}=URNDM(IXX)-URNDM(JXX); IF({P1}.LT.0.) {P1}={P1}+1.;
    URNDM(IXX) = {P1};
    IXX=IXX-1; IF(IXX.EQ.0) IXX=97;
    JXX=JXX-1; IF(JXX.EQ.0) JXX=97;
    CRNDM=CRNDM-CDRNDM; IF(CRNDM.LT.0.) CRNDM=CRNDM+CMRNDM;
    {P1}={P1}-CRNDM; IF({P1}.LT.0.) {P1}={P1}+1.;
   ]
   }

"This should be called somewhere near the beginning of the main routine"
"before any random numbers are asked for";
REPLACE {$RNG-INITIALIZATION;} WITH {;
 {SETR B=$RNGEN}
 [IF] {COPY B}=0 [;]
 [IF] {COPY B}=1 [ IXX=0; JXX=0; CALL RMARIN;
      DO II=1,20005[
      $RANDOMSET XRANM;
      IF(II.GT.20000) OUTPUT (MOD(INT(XRANM*16.**JJ),16),JJ=1,7);
      (8X,7I3); ]
    ]
 }

"-------------ranmar.correlations---------------"
"This is ranmar.correlations (SID 1.8 last edited 18 Dec 1996)"
%C80
;
"**********************************************************************"
"                                                                      "
"                  ranmar.correlations                                 "
"                  *******************                                 "
"                                                                      "
"  Macro set for doing restarts and correlations                       "
"                                                                      "
"  Coding for the EGS4 system by:                                      "
"                                                                      "
"  Alex F Bielajew  89/12/21  Version 1.0                              "
"  Institute for National Measurement Standards                        "
"  National Research Council of Canada                                 "
"  Ottawa, CANADA                                                      "
"  KIA OR6                                                             "
"                                                                      "
" 95/11/15  changed STORE-RNG  so -re argument does not cause bomb DR  "
"             also exlicitly included types in RANDOM                  "
"                                                                      "
" 96/08/09  added r4opt to random def'n and in RANDOMSET   DR          "
"                                                                      "
" 96/12/18  Removed redundant declaration of                           "
"           $RANDOMSET                                                 "
"           $COMMON-RANDOM-DECLARATION-IN-BLOCK-DAT                    "
"           and                                                        "
"           $RNG-INITIALIZATION                                        "
"           Only home for  these is in ranmar.macros - BLIF            "
"                                                                      "
"**********************************************************************"
;
REPLACE {$STORE-RNG(#);} WITH {
;IDUM2 = {P1};
;IF(IDUM2.EQ.0)[
      DO IDUM=1,97[UDM0(IDUM)=URNDM(IDUM);]
      CDM0=CRNDM;CDDM0=CDRNDM;CMDM0=CMRNDM;IXXDM0=IXX;JXXDM0=JXX;
      ]
  ELSEIF(IDUM2.EQ.-1)[
      DO IDUM=1,97[UDM1(IDUM)=URNDM(IDUM);]
      CDM1=CRNDM;CDDM1=CDRNDM;CMDM1=CMRNDM;IXXDM1=IXX;JXXDM1=JXX;
      ]
  ELSEIF(IDUM2.EQ.-2)[
      DO I=1,97[UDM2(IDUM)=URNDM(IDUM);]
      CDM2=CRNDM;CDDM2=CDRNDM;CMDM2=CMRNDM;IXXDM2=IXX;JXXDM2=JXX;
      ]
  ELSE[
      WRITE(IDUM2,*)URNDM,CRNDM,CDRNDM,CMRNDM,IXX,JXX;
      ]
}
;
REPLACE {$RESET-RNG(#);} WITH {
;IDUM2 = {P1};
;IF(IDUM2.EQ.0)[
      DO IDUM=1,97[URNDM(IDUM)=UDM0(IDUM);]
      CRNDM=CDM0;CDRNDM=CDDM0;CMRNDM=CMDM0;IXX=IXXDM0;JXX=JXXDM0;
      ]
  ELSEIF(IDUM2.EQ.-1)[
      DO IDUM=1,97[URNDM(IDUM)=UDM1(IDUM);]
      CRNDM=CDM1;CDRNDM=CDDM1;CMRNDM=CMDM1;IXX=IXXDM1;JXX=JXXDM1;
      ]
  ELSEIF(IDUM2.EQ.-2)[
      DO IDUM=1,97[URNDM(IDUM)=UDM2(IDUM);]
      CRNDM=CDM2;CDRNDM=CDDM2;CMRNDM=CMDM2;IXX=IXXDM2;JXX=JXXDM2;
      ]
  ELSE[
      READ(IDUM2,*)URNDM,CRNDM,CDRNDM,CMRNDM,IXX,JXX;
      ]
}

;
"-------------end of ranmar.correlations---------------"

"------------------------------------------------------------------"
"      PLACE COMPILER DEPENDENT SUBROUTINE CALL HERE               "
"------------------------------------------------------------------"
" Select Fortran Compiler.                                         "
" Lahey Fortran = 1                                                "
" Microsoft Fortran = 2                                            "
" Other PC = 3 (default)                                           "
" g77 on Windows  = 4                                              "
" Sun UNIX Workstation and Linux = 5                               "
" Other UNIX Workstation =6                                        "
"------------------------------------------------------------------"
REPLACE {$COMPILER} WITH {4}
"------------------------------------------------------------------"

"------------------------------------------------------------------"
"Macro to select the timer to be used (compiler dependent).        "
"------------------------------------------------------------------"
REPLACE {$TIMERSET;} WITH {;}

REPLACE {$TIME-NOW#;} WITH {
  {SETR B=$COMPILER}
  [IF] {COPY B}=1 [CALL TIMER({P1});]
  [IF] {COPY B}=2 [CALL GETTIM(IHR,IMIN,ISEC,I100);
                  {P1}=(IHR*3600+IMIN*60+ISEC)*100+I100;]
  [IF] {COPY B}=3 [{P1}=0.0;]
  [IF] {COPY B}=4 [TT=ETIME(TARRAY);
                  {P1}=TARRAY(1)*100.0;]
  [IF] {COPY B}=5 [TT=ETIME(TARRAY);
                  {P1}=TARRAY(1)*100.0;]
  [IF] {COPY B}=6 [{P1}=0.0;]
}

"------------------------------------------------------------------"
"Macro to define DIMENSION related to the timer to be used          "
"                                    (compiler dependent).         "
"------------------------------------------------------------------"
REPLACE {$TIME-DIM;} WITH {
  {SETR B=$COMPILER}
  [IF] {COPY B}=1 [;]
  [IF] {COPY B}=2 [;]
  [IF] {COPY B}=3 [;]
  [IF] {COPY B}=4 [REAL TARRAY(2);]
  [IF] {COPY B}=5 [REAL TARRAY(2);]
  [IF] {COPY B}=6 [;]
}

"------------------------------------------------------------------"
"Macro to define DIMENSION related to the timer to be used          "
"                                    (compiler dependent).         "
"------------------------------------------------------------------"
REPLACE {$TIME-DIM;} WITH {
  {SETR B=$COMPILER}
  [IF] {COPY B}=4 [REAL TARRAY(2);]
  [ELSE]           [;]
}

"------------------------------------------------------------------"
"Macro to define OPEN STATEMENT for Cross-section data.             "
"                                            (UNIX or PC).         "
"------------------------------------------------------------------"

REPLACE {$OPEN;} WITH {
  {SETR B=$COMPILER}
  [IF] {COPY B}<5 [OPEN(12,FILE='mortjob.xse',status='old');
```

```
                   OPEN(6,FILE='mortjob.out',status='unknown');
                   OPEN(8,FILE='mortjob.dum',status='unknown');
                   OPEN(UNIT=90,FILE='USER.F90',STATUS='UNKNOWN');]
  [ELSE]          [OPEN(12,FILE='mortjob.xsec',status='old');
                   OPEN(6,FILE='mortjob.output',status='unknown');
                   OPEN(8,FILE='mortjob.dummy',status='unknown');
                   OPEN(UNIT=90,FILE='USER.F90',STATUS='UNKNOWN');]
}

"COMMON to define variables to score at AUSGAB"
"DEPE1:deposited energy inside the detector 1"
"DEPE2:deposited energy inside the detector 2"
"DELTAE:energy bin width in MeV"

REPLACE {;COMIN/TOTALS/;} WITH
{;COMMON/TOTALS/DEPE1,DEPE2,DELTAE;}

"COMMON of print-out parameter"

REPLACE {;COMIN/LINES/;} WITH
{;COMMON/LINES/NLINES,NWRITE,NCOUNT,ILINES;}

"COMMON of geometry related parameter"

REPLACE {;COMIN/PASSIT/;} WITH
{;COMMON/PASSIT/NREG;}

PARAMETER $NCASES=5000; "MAXIMUN NUNBER OF CASES"
PARAMETER $MATNO=3;     "Number of material used"
PARAMETER $NBATCH=50;   "Number of batch"
PARAMETER $NEBIN=50;    "Number of energy bin"

"******************************************************************"
"******************* ADDITIONAL (NON-EGS) MACROS ******************"
"******************************************************************"

"                      N O N E                                    "

"******************************************************************"
"************************** DECLARATIONS **************************"
"******************************************************************"

;COMIN/DEBUG,BOUNDS,BREMPR,EDGE,ELECIN,ETALY1,GEOM,LINES,MEDIA,MISC,
NTALY1,PASSIT,RANDOM,STACK,THRESH,TOTALS,UPHIOT,USEFUL,USER/;
DIMENSION PH1($NEBIN),PH1PB($NEBIN,$NBATCH);
DIMENSION PH2($NEBIN),PH2PB($NEBIN,$NBATCH);
DIMENSION PHA($NEBIN),PHAPB($NEBIN,$NBATCH);
DIMENSION PEFPB($NBATCH),TEFPB($NBATCH);
REAL*8 TOTKE,AVAILE,DEPE1,DEPE2;
       "NEEDED FOR ENERGY CONSERVATION TABULATION"

$TYPE   MEDARR(24,$MATNO);
DATA MEDARR/$S'GE-IAPRIM',15*' ',
            $S'NAI-IAPRIM',14*' ',
            $S'AIR-IAPRIM',14*' '/;


"******************************************************************"
"*************** START OF EXECUTABLE CODE *************************"
"******************************************************************"

$OPEN;

"******************************************************************"
"******** STEP 2.  PRE-HATCH-CALL-INITIALIZATION COMES NEXT *******"
"******************************************************************"
NMED=$MATNO; "NUMBER OF MEDIA"

DO J=1,NMED [
DO I=1,24 [MEDIA(I,J)=MEDARR(I,J);]]

ITBODY=0;
IRPPIN=0;ISPHIN=0;IRCCIN=0;ITORIN=0;ITRCIN=0;
IZONIN=0;IZONAD=0;
ITVERR=0;
IGMMAX=0;

IFTI = 90;
IFTO = 6;
CALL GEOMGT(IFTI,IFTO,IGMMAX,ITBODY);
```

```
NREG=IZONIN;

MED(NREG)=0;   "VACUUM REGIONS"

MED(1)=1;   "Ge detector"
MED(2)=3;   "Air region"
MED(3)=2;   "NAI"
MED(4)=3;   "Collimator region"

/ECUT(1),ECUT(3)/=0.561;

IEDGFL(1)=32;  "53:Atomic number of Ge"
"                0:X ray of Ge is not produced"
IEDGFL(3)=53;  "53:Atomic number of I"
"                0:X ray of I is not produced"

"******************************************************************"
"***************** STEP 3.  HATCH-CALL COMES NEXT *****************"
"******************************************************************"

CALL HATCH;

"OUTPUT VARIOUS QUANTITIES ASSOCIATED WITH THE MEDIA"

OUTPUT;  ('1QUANTITIES ASSOCIATED WITH EACH MEDIA:',//);

DO J=1,NMED [
OUTPUT (MEDIA(I,J),I=1,24);  (/,1X,24A1);
OUTPUT RHO(J),RLC(J);  (5X,' RHO=',G15.7,' G/CM**3     RLC=',
   G15.7,' CM');
OUTPUT AE(J),UE(J);  (5X,' AE=',G15.7,' MEV    UE=',G15.7,' MEV');
OUTPUT AP(J),UP(J);  (5X,' AP=',G15.7,' MEV    UP=',G15.7,' MEV');
]

OUTPUT;(/' INFORMATION OF MEDIUM AND CUT-OFFFOR EACH REGION'//);
DO I=1,NREG [
IF(MED(I).EQ.0) [OUTPUT I,ECUT(I),PCUT(I);
(' MEDIUM(',I3,')=VACUUM',18X,'ECUT=',G10.5,' MEV, PCUT=',G10.5,' MEV');
]
ELSE [OUTPUT I,(MEDIA(II,MED(I)),II=1,24),ECUT(I),PCUT(I);
(' MEDIUM(',I3,')=',24A1,'ECUT=',G10.5,' MEV, PCUT=',G10.5,' MEV');]
]

DO I=1,NREG [IF(IEDGFL(I).NE.0) [CALL EDGSET(NREG); EXIT;]]

"******************************************************************"
"*********** STEP 4.  HOWFAR-INITIALIZATION COMES NEXT ************"
"******************************************************************"

"******************************************************************"
"********** STEP 5.  INITIALIZATION FOR AUSGAB COMES NEXT *********"
"******************************************************************"

CALL ECNSV1(0,NREG,TOTKE);"  INITIALIZE ESUM ARRAY FOR ENERGY"
"                            CONSERVATION CALCULATION."
"                            NREG=NUMBER OF REGIONS"
"                            TOTKE=TOTAL KE (DUMMY VARIABLE HERE)"
"                                  (MUST BE REAL*8)"

CALL NTALLY(0,NREG);

NCOUNT=0;  "PARTICLE HISTORY COUNTER"
ILINES=0;  "INITIALIZE LINE-OUTPUT COUNTER"
/DEPE1,DEPE2/=0.D0; "ZERO THE ENERGY DEPOSITION AT SCINTILATOR"
/PEF,TEF/=0.0;  "Zero the efficiency"

DO J=1,$NEBIN [/PH1(J),PH2(J),PHA(J)/=0.0;]  "Zero the pulse-height"

"******************************************************************"
"****** STEP 6.  DETERMINATION OF INCIDENT PARTICLE PROPERTIES ****"
"******************************************************************"

IQI=0;  "INCIDENT PARTICLE"

EI=1.33 +ABS(IQI)*PRM;   "TOTAL ENERGY OF PARTICLE (MEV) "

AVAILE=EI + IQI*PRM;  "AVAILABLE K.E. (MEV) (MUST BE REAL*8)"
EKIN=AVAILE;
ECUTMN=ECUT(4); EKO=EKIN;  "*PRESTA*"
$PRESTA-INPUTS;  "INPUT THE *PRESTA* VARIABLES"

DELTAE=0.05;  "Energy bin of response"
```

```
XI=0.0; YI=0.0; ZI=6.5;  "STARTING COORDINATES (CM)"
UI=0.0; VI=0.0; WI=1.0;  "INCIDENT DIRECTION COSINES"
SDTE=1.0;                "Source detector distance in cm"
DIST=SDET+ZI;
RRR=SQRT(DIST*DIST+ZI*ZI);
WIMAX=-DIST/RRR;          "Maximum WI value"

IRI=2;  "ENTRANCE REGION DEFINITION"
WTI=1.0;  "WEIGHT FACTOR OF UNITY"

IDINC=-1; "AN IDENTIFIER (LIKE IARG) TO MARK INCIDENT PARTICLES"

IXXST=-1994107751;
IXX=IXXST;  "INITIALIZED RANDOM NUMBER WITH STARTING SEED"

$RNG-INITIALIZATION;

NWRITE=10;  "NUMBER OF INCIDENT CASES TO PRINT OUT"

NCASES=$NCASES; "MAXIMUM NUMBER OF INCIDENT CASES TO RUN"
NBATCH=$NBATCH;  "NUMBER OF BATCH"
NCASPB=NCASES/NBATCH; "NUMBER OF CASES PER BATCH"
NOFBAT=0;  "NUMBER OF BATCH FINISHED"

NLINES=30; "NUMBER OF LINES TO PRINT OUT"


"******************************************************************"
"******************** STEP 7. SHOWER-CALL---NEXT ******************"
"******************************************************************"

DO NOFBAT=1,NBATCH [ "BATCH-LOOP"

DO I=1,NCASPB ["START OF SHOWER CALL LOOP OF EACH BATCH"

"Determine directional cosine"
$RANDOMSET WI0;
WI=(WIMAX+1.0)*WI0-1.0;
$RANDOMSET PHAI0;
PHAI=PI*(2.0*PHAI0-1.0);
SINTH=SQRT(1.0-WI*WI);
UI=COS(PHAI)*SINTH;
VI=SIN(PHAI)*SINTH;

"Calculate incident X and Y position and region"
DIST=SDTE/WI;
XI=SDTE*UI;
YI=SDTE*VI;
RRR=SQRT(XI*XI+YI*YI);
IF(RRR.LE.0.25) [IRI=4;  "Inside collimator"]
ELSE [IRI=3;  "Incident on NaI"]

IF(NCOUNT.LE.NWRITE.AND.ILINES.LE.NLINES) [
  OUTPUT EI,XI,YI,ZI,UI,VI,WI,
  IQI,IRI,IDINC;   (7G15.7,3I5);
  ILINES=ILINES+1;]

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

"If some energy is deposited inside detector add pulse-height"
"and efficiency"

IF(DEPE1.GT.0.D0) [
IE=DEPE1/DELTAE+1;
IF(IE.LE.$NEBIN) [PH1(IE)=PH1(IE)+WTI;]
IF(DEPE1.GE.EI*0.999) [PEF=PEF+WTI;]
IF(DEPE2.EQ.0.0) [
"No energy deposition at detector 2"
PHA(IE)=PHA(IE)+WTI;
]
TEF=TEF+WTI;]
IF(DEPE2.GT.0.D0) [
IE=DEPE2/DELTAE+1;
IF(IE.LE.$NEBIN) [PH2(IE)=PH2(IE)+WTI;]
]

/DEPE1,DEPE2/=0.D0;

NCOUNT=NCOUNT + 1;
IXXEND=IXX;   "LAST RANDOM NUMBER USED"
```

```
] "End of SHOWER CALL loop for each BATCH"

"Calculate average value for this BATCH"

DO IE=1,$NEBIN [
PH1PB(IE,NOFBAT)=PH1(IE)/NCASPB;
PH2PB(IE,NOFBAT)=PH2(IE)/NCASPB;
PHAPB(IE,NOFBAT)=PHA(IE)/NCASPB;
/PH1(IE),PH2(IE),PHA(IE)/=0.0;
]
PEFPB(NOFBAT)=PEF/NCASPB;
TEFPB(NOFBAT)=TEF/NCASPB;
/PEF,TEF/=0.0;

]  "End of BATCH-loop"

TOTKE=NCOUNT*AVAILE; "TOTAL (AVAILABLE) K.E."

"******************************************************************"
"******************** STEP 8. OUTPUT OF RESULTS *******************"
"******************************************************************"

OUTPUT NCOUNT,IXXST,IXXEND,AVAILE,TOTKE;
('1',I10,' CASES COMPLETED',
     //,' IXXST=',I12,/,' IXXEND=',I12,//,' AVAILABLE K.E.=',
     G15.5,' MEV',/,' TOTKE=',E15.5,' MEV',//);

OUTPUT;(/' PRESTA algorithm is used'/);

OUTPUT EI,SDTE;(' Results for ',G15.5,'MeV photon'/
' at ',F10.4,'cm from detector surface'/);

"Calculate average and its deviation"

/AVPE,DESCI2/=0.0;
DO J=1,NBATCH [
AVPE=AVPE+PEFPB(J)/NBATCH;
DESCI2=DESCI2+PEFPB(J)*PEFPB(J)/NBATCH;
]
SIGPE=SQRT((DESCI2-AVPE*AVPE)/(NBATCH-1));
AVPE=AVPE*100.0;
SIGPE=SIGPE*100.0;
OUTPUT AVPE,SIGPE;(' Peak efficiency =',G15.5,'+-',G15.5,' %');

/AVTE,DESCI2/=0.0;
DO J=1,NBATCH [
AVTE=AVTE+TEFPB(J)/NBATCH;
DESCI2=DESCI2+TEFPB(J)*TEFPB(J)/NBATCH;
]
SIGTE=SQRT((DESCI2-AVTE*AVTE)/(NBATCH-1));
AVTE=AVTE*100.0;
SIGTE=SIGTE*100.0;
OUTPUT AVTE,SIGTE;(' Total efficiency =',G15.5,'+-',G15.5,' %');

OUTPUT ;(/' Pulse height distribution of detector 1');
DO IE=1,$NEBIN [
ELOW=DELTAE*(IE-1);
EUP=DELTAE*IE;
IF(ELOW.GT.EKIN) [EXIT;]

/AVPH,DESCI2/=0.0;
DO J=1,NBATCH [
AVPH=AVPH+PH1PB(IE,J)/NBATCH;
DESCI2=DESCI2+PH1PB(IE,J)*PH1PB(IE,J)/NBATCH;
]
SIGPH=SQRT((DESCI2-AVPH*AVPH)/(NBATCH-1));
OUTPUT EUP,AVPH,SIGPH;
(' E (upper-edge --',G10.4,' MeV )=',G15.5,'+-',G15.5,
' counts/bin/incident');
]

OUTPUT ;(//' Pulse height distribution of detector 2');
DO IE=1,$NEBIN [
ELOW=DELTAE*(IE-1);
EUP=DELTAE*IE;
IF(ELOW.GT.EKIN) [EXIT;]

/AVPH,DESCI2/=0.0;
DO J=1,NBATCH [
AVPH=AVPH+PH2PB(IE,J)/NBATCH;
DESCI2=DESCI2+PH2PB(IE,J)*PH2PB(IE,J)/NBATCH;
```

```
]
SIGPH=SQRT((DESCI2-AVPH*AVPH)/(NBATCH-1));
OUTPUT EUP,AVPH,SIGPH;
(' E (upper-edge --',G10.4,' MeV )=',G15.5,'+-',G15.5,
' counts/bin/incident');
]

OUTPUT ;
(//' Pulse height distribution of detector 1 with anti-coincidence');
DO IE=1,$NEBIN [
ELOW=DELTAE*(IE-1);
EUP=DELTAE*IE;
IF(ELOW.GT.EKIN) [EXIT;]

/AVPH,DESCI2/=0.0;
DO J=1,NBATCH [
AVPH=AVPH+PHAPB(IE,J)/NBATCH;
DESCI2=DESCI2+PHAPB(IE,J)*PHAPB(IE,J)/NBATCH;
]
SIGPH=SQRT((DESCI2-AVPH*AVPH)/(NBATCH-1));
OUTPUT EUP,AVPH,SIGPH;
(' E (upper-edge --',G10.4,' MeV )=',G15.5,'+-',G15.5,
' counts/bin/incident');
]

"NEXT, CALL THE SUBROUTINE ECNSV1 TO WRITE-OUT THE ENERGY DEPOSITION"
"TOTALS---TO CHECK ENERGY CONSERVATION FOR ONE THING"

CALL ECNSV1(1,NREG,TOTKE);

CALL NTALLY(1,NREG);

STOP;
END;  "END OF MAIN PROGRAM"

%E
"******************************************************************"
"                                STANFORD LINEAR ACCELERATOR CENTER"
SUBROUTINE AUSGAB(IARG);
"                                EGS4 SUBPROGRAM -  8 MAY 1983/1730"
"******************************************************************"
;COMIN/DEBUG,EPCONT,ETALY1,LINES,MISC,NTALY1,PASSIT,STACK,TOTALS,
       USEFUL/;
REAL*8 DPWT,DEPE1,DEPE2;
IRL=IR(NP);   "SET LOCAL VARIABLE"
DPWT=WT(NP);

"KEEP TRACK OF THE ENERGY DEPOSITION---FOR CONSERVATION PURPOSES"
ESUM(IQ(NP)+2,IRL,IARG+1)=ESUM(IQ(NP)+2,IRL,IARG+1)+EDEP*DPWT;
NSUM(IQ(NP)+2,IRL,IARG+1)=NSUM(IQ(NP)+2,IRL,IARG+1) + 1;

IF(MED(IRL).EQ.1) ["particle is inside the detector 1"
DEPE1=DEPE1+EDEP;  "Add energy deposition"]

IF(MED(IRL).EQ.2) ["particle is inside the detector 2"
DEPE2=DEPE2+EDEP;  "Add energy deposition"]

IF(NCOUNT.LE.NWRITE.AND.ILINES.LE.NLINES) [
OUTPUT E(NP),X(NP),Y(NP),Z(NP),U(NP),V(NP),W(NP),
  IQ(NP),IRL,IARG;   (7G15.7,3I5);
ILINES=ILINES+1;]

RETURN;
END;  "END OF SUBROUTINE AUSGAB"

%E


"******************************************************************"
"*********************** ucsampl2cgp end **************************"
"******************************************************************"
%N
```