DEVELOPMENT OF AN EGS4/PRESTA USER CODE WRITTEN BY THE CG DESCRIPTION

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Abstract

The geometry description of radiation shielding codes, such as QAD-CG and MORSE-CG, is often written by the combinatorial geometry (CG) method. However any EGS4/PRESTA user code with the CG method is not yet reported. Since the macro, called $CALL-HOWNEAR, is necessary to use the PRESTA algorithm on EGS4, it is difficult to write complicated geometries on EGS4/PRESTA. Then we developed an EGS4/PRESTA user code, which can be written by 3 dimensional CG method and it did the way that can evaluate influence of the step size for low energy electrons and influence of a calculative geometry. This paper described an user code using the CG method, named PRESTA-CG. Furthermore we reported comparison of the response of an ionization chamber with the UCSAMPCG which is employed the CG description for original EGS4.

1. Introduction

For the application of EGS4[1] to simulate electro-magnetic shower for a thin detector and gas detector, EGS4 cannot simulate well. To resolve this problem, the ESTEPE option[2],which reduces the step size of an electron from the default value, was used for examples by Lindstrom et al.. However ESTEPE is still a pragmatic restriction of the step-size and depends on both the material and its size. Also, calculations using the ESTEPE option take more CPU-time than do those with the default EGS4 especially for small ESTEPE value. As a more logical and convenient method to overcome these difficulties,the PRESTA algorithm(Parameter Reduced Electron-Step Transport Algorithm)[3],which was developed by Bielajew and Rogers to improve the electron transport in EGS4 in the low-energy region, was tested for a simulation of a sampling calorimeter. The PRESTA algorithm involves a path-length correction algorithm,a lateral correction algorithm and a boundary crossing algorithm.

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To use EGS4, the user must write a "User Code". This consists of MAIN program and the subroutines HOWFAR and AUSGAB. A number of geometry subprograms and their macro equivalents are distributed with the EGS4 Code Systems in order to make it easier to write HOWFAR.

However any EGS4/PRESTA user code with the CG method is not yet reported. Since the macro, called $CALL-HOWNEAR, is necessary to use the PRESTA algorithm on EGS4, it is difficult to write complicate geometries on EGS4/PRESTA. Then we developed an EGS4/PRESTA user code, which can be written by 3 dimensional CG method and it did the way that can evaluate influence of step size of low energy electrons and influence of calculative geometry. This paper described an user code using CG method, named PRESTA-CG.

2. How to create user code

Main point of making of the PRESTA-CG user code is definition of the macro $CALL-HOWNEAR and the subroutine HOWFAR[4,5](refer table 1). We show the scheme in the following.

(1) Definition of the macro $CALL-HOWNEAR(#).
We defined the macro $CALL-HOWNEAR(#) with the CG method(refer table 2). The macro $CALL-HOWNEAR(#) gives minimal length, that becomes necessary when we use the PRESTA, from current position of corpuscle to zone boundary. Actually the CG method definition RPP,RCC,SPH is added and made the subroutine HWNEAR dealing with the CALL form.

(2) Definition of a macro that corpuscle seeks for distance to current zone boundary in flight direction.
We made the macro $RPPCG1,$RCCCG1,$SPHCG1 seeking for a zone boundary in the CG method(refer table 3).

(3) Definition of macro that find inclusion relation of corpuscle and zone.
We made the macro $RPPCGSH, $RCCCGSH, $SPHCGSH, $SEARCHZON that find inclusion relation of corpuscle place and zone in CG method(refer table 4).

(4) Definition of the COMIN/GEOM/.
We replaced the COMIN/GEOM/ by COMMON name RPPDAT, RCCDAT, SPH-DAT, ZONDTA, TVALCG to define the CG method(refer table 5).

(5) Definition of PRESTA control flag.

We added macro $PRESTA-ON for the control that PRESTA carries out handling.

(6) Definition in MAIN routine.

We added following definition in the MAIN routine.

The $PRESTA-INPUTS, initial setting of PRESTA.

The CG method definition data, such as RCC, RPP and SPH(refer figure 1).

The Variables ECUTMN and EK0 for PRESTA.

The addition of COMIN/ELECIN/.

(7) Preparation of subroutine HOWFAR.

Because we let next place and zone of corpuscle decide in HOWFAR from step size and distance to boundary, we made a subroutine HOWFAR coresponding to the CG method.

(8) Preparation of a CONFIGURATION file.

We carried out definition of effect using NRC4MACP.MORTRAN and NRCCAUXP.MORTRAN to a CONFIGURATION file.

3. Computational Results

We reported comparison of the response of an ionization chamber(Radocon 550-3 type) with the UCSAMPCG which is employed the CG description for original EGS4 (refer Table 6).

The calculated results of the PRESTA-CG code are shown in Figure 1. And the response, that we changed ESTEPE by a ESTEPE option, are shown in figure 2. The response used PRESTA-CG is good agreement with that for UCSAMPCG on ESTEPE of 0.05 or lower. It confirms that the PRESTA-CG is useful for the calculation an complex geometry.

4. Conclusions

We have written EGS4/PRESTA by 3 dimensional CG method. This PRESTA-CG can evaluate influence of the step size for low energy electrons and calculate transport under complex geometry. Since the PRESTA-CG is added the fundamental geometry, such as cone, easily, we are extending this code now.

Acknowledgments

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References

[1] W.R.Nelson,H.Hirayama and D.W.O.Rogers, *The EGS4 Code System*, SLAC-265 (1985).

[2] D.W.O.Rogers, Nucl. Instr. and Meth. **A227**, 535 (1984).

[3] A.F.Bielajew and D.W.O.Rogers, *The Parameter Reduced Electron-Step Transport Algorithm for Electron Monte Carlo Transport*, Nucl. Instr. and Meth., **B18**, 165 (1987).

[4] H. Hirayama, *Advanced Manual for using EGS4* (in Japanese), Proceeding of the Second EGS4 User's Meeting in Japan KEK, Japan, 20-22 (1992).

[5] H.Hirayama, *MC-Simulations with EGS4/PRESTA for an Electro-Magnetic Sampling Calorimeter*, IEEE Trans. Nucl. Sci., **NS-40**, 503 (1993).

Table 1: PRESTA construction in the EGS4 code

```
%E "EGS4.MOR RECEIVED VIA BITNET JAN 29 AT NRCC +MINOR CHANGES"
"******************************************************************"
"                               STANFORD LINEAR ACCELERATOR CENTER"
SUBROUTINE ELECTR(IRCODE);
"                                 VERSION 4.00 -- 26 JAN 1986/1900"
"******************************************************************"
      .
      .
$SET-TUSTEP; "TUSTEP RESTRICTION MACRO TEMPLATE"
      .
      .
RETURN; "I.E., RETURN TO SHOWER"
END; "END OF SUBROUTINE ELECTR"

------------------------------------------------------------------------

REPLACE {$SET-TUSTEP;} WITH
  {;TUSTEP=AMIN1(TUSTEP,RANGE);$BOUNDARY-CROSSING-ALGORITHM;}

"THIS IS THE PRESTA VERSION THAT SETS TUSTEP. AT THIS STAGE THE BOUNDARY "
"CROSSING ALGORITHM IS INVOKED.                                          "

------------------------------------------------------------------------

REPLACE {$BOUNDARY-CROSSING-ALGORITHM;} WITH
  {;IF(IBCA.EQ.0)[
      $CALL-HOWNEAR(TPERP);
      DNEAR(NP)=TPERP;
      USTMIN=(OMEGMN/BLCC(MEDIUM))*EKE*(EIE+RM)/EIE**2;
      TUSTEP=MIN(TUSTEP,MAX(TPERP,USTMIN));
      IF(TUSTEP.GT.TPERP)[ISHRTN=0;]ELSE[ISHRTN=1;]]}

"THIS IS THE PRESTA BOUNDARY CROSSING ALGORITHM. IT CALCULATES THE SHORTEST "
"DISTANCE TO THE CLOSEST BOUNDING SURFACE AND EQUATES TUSTEP TO IT UNLESS   "
"LESS THAN THE MINIMUM SPECIFIED BY THE USER.                               "
"NOTE ALSO THAT DNEAR IS CALCULATED FOR CHARGED PARTICLES AT THIS STAGE IF  "
"IBCA IS SET TO 0. THE USER SHOULD BE AWARE OF THIS TO AVOID ANY REDUNDANCY."
```

Table 2: Definition of the macro $CALL-HOWNEAR(#)

```
REPLACE{$CALL-HOWNEAR(#);}
 WITH{$CALL-HOWNEAR-FOR-COMBINATORIAL-GEOMETRY({P1 });}

"THIS IS THE MACRO THAT SHOULD RETURN THE CLOSEST PERPENDICULAR DISTANCE TO "
"ANY SURFACE WHICH FORMS A BOUNDARY FOR THE CURREN IN THIS                  "
"APPLICATION IT IS REPLACED BY THE MACRO FOLLOWING WHICH IS SPECIALIZED FOR "
"THE COMBINATORIAL GEOMETRY.                                                "
"IT IS THE USER'S RESPONSIBILITY TO PROVIDE THIS MACRO FOR HIS OWN GEOMETRY."

PARAMETER $MAXDELL=1.0E+30;      "MAX. OF USTEP CHECK"

REPLACE{$CALL-HOWNEAR-FOR-COMBINATORIAL-GEOMETRY(#);} WITH
   {;XL=X(NP);YL=Y(NP);ZL=Z(NP);IRL=IR(NP);
     CALL HWNEAR({P1},XL,YL,ZL,IRL); }

SUBROUTINE HWNEAR(TPERP,XLS,YLS,ZLS,IRL);
    REAL*4 XLS,YLS,ZLS;
    COMIN/GEOM/;
    REAL*8 XL,YL,ZL;
    REAL*8 P1MIN,CLONG1,CLONG2,CLONG3,CLONG4,CLONG5,CLONG6;
    REAL*8 ACYL,BCYL,CCYL;
    XL=XLS;YL=YLS;ZL=ZLS;
    P1MIN=$MAXDELL;
    DO I=1,NBBODY(IRL) [
         .
         .
      DO J=1,ISPHIN [
       IF(IABS(NBZONE(I,IRL)).EQ.NBSPH(J)) [
         CLONG1=DABS(XL-SPHPNT(1,J));
         CLONG2=DABS(YL-SPHPNT(2,J));
         CLONG3=DABS(ZL-SPHPNT(3,J));
         CLONG4=DABS(SPHPNT(4,J)
              -DSQRT(CLONG1*CLONG1+CLONG2*CLONG2+CLONG3*CLONG3));
         P1MIN=DMIN1(CLONG4,P1MIN);
       ]]
         .
         .
   ]
   TPERP=P1MIN;
   RETURN;
   END; "END OF SUBROUTINE HWNEAR"
```

Table 3: The macro $SPHCG1

```
"-------------------------------------------------------------------"
"         MACRO-ROUTINE FOR SPH GEOMETRY (CG VERSION)               "
"-------------------------------------------------------------------"

PARAMETER $MXSPH=50;       "MAX. NO. OF SPHERES"
PARAMETER $DELSPH=1.0E-04; "CLOSEST ALLOWABLE DISTANCE TO SURFACE"

"SPHCG1------COMMON BLOCK FOR $SPHCG1 MACRO"

REPLACE {;COMIN/SPHDTA/;} WITH
  {;REAL*8 SPHPNT;COMMON/SPHDTA/SPHPNT(4,$MXSPH),NBSPH($MXSPH),ISPHIN;}

REPLACE {$SPHCG1(#);}
WITH{;UDOTAU=U(NP);UDOTAV=V(NP);UDOTAW=W(
NP);
  XL=X(NP);YL=Y(NP);ZL=Z(NP);
  CALL SPHCG1({P1},XL,YL,ZL,UDOTAU,UDOTAV,UDOTAW);}


SUBROUTINE SPHCG1(IZON,XLS,YLS,ZLS,UNP,VNP,WNP);
 COMIN/GEOM/;
 REAL*4 XLS,YLS,ZLS,UNP,VNP,WNP;
 REAL*8 XL,YL,ZL,UDOTAU,UDOTAV,UDOTAW,UDOTR;
 REAL*8 ASPH,BSPH,CSPH,ARGSP,ROOTSP;
 UDOTAU=UNP;UDOTAV=VNP;UDOTAW=WNP;XL=XLS;YL=YLS;ZL=ZLS;ASPH=1.0;
   BSPH=((XL-SPHPNT(1,IZON))*UDOTAU+(YL-SPHPNT(2,IZON))*UDOTAV
       + (ZL-SPHPNT(3,IZON))*UDOTAW)/ASPH;
   CSPH=(XL-SPHPNT(1,IZON))*(XL-SPHPNT(1,IZON))
       +(YL-SPHPNT(2,IZON))*(YL-SPHPNT(2,IZON))
       +(ZL-SPHPNT(3,IZON))*(ZL-SPHPNT(3,IZON))
       -SPHPNT(4,IZON)*SPHPNT(4,IZON);
   ARGSP=BSPH*BSPH-CSPH;
   IF(ARGSP.GE.0.0) [
     ROOTSP=DSQRT(ARGSP);
     IF(CSPH.LE.0.) [              " INSIDE"
       UDOTR=(-BSPH+ROOTSP)/ASPH;
       IF(UDOTR.GE.0.) [ITVALM=ITVALM+1;ATVAL(ITVALM)=UDOTR;]
     ]
     ELSE [
       UDOTR=(-BSPH-ROOTSP)/ASPH;
       IF(UDOTR.GE.0.) [ITVALM=ITVALM+1;ATVAL(ITVALM)=UDOTR;]
       UDOTR=(-BSPH+ROOTSP)/ASPH;
       IF(UDOTR.GE.0.) [ITVALM=ITVALM+1;ATVAL(ITVALM)=UDOTR;]
     ]
   ]
   RETURN;
   END;
```

Table 4: The macro $SPHCGSH

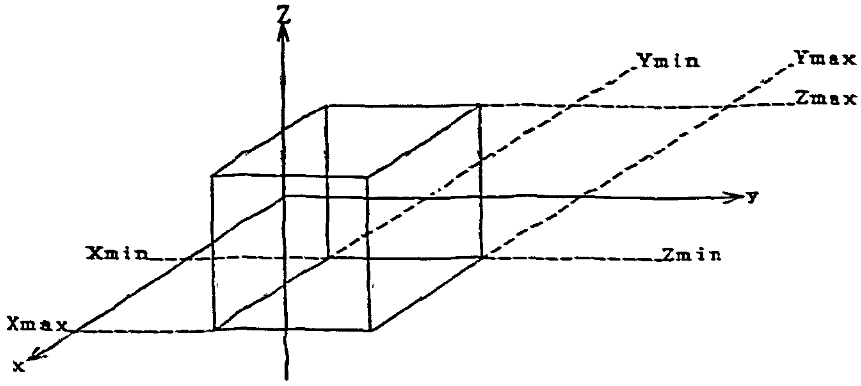
```
"$SPHCGSH---MACRO REPLACEMENT FOR SUBROUTINE SPHCGSH"

REPLACE {$SPHCGSH(#,#,#,#,#,#);}
WITH{;IF(({P3}-SPHPNT(1,{P1}))*({P3}-SPHPNT(1,{P1}))
     +({P4}-SPHPNT(2,{P1}))*({P4}-SPHPNT(2,{P1}))
     +({P5}-SPHPNT(3,{P1}))*({P5}-SPHPNT(3,{P1}))
       .GT.SPHPNT(4,{P1})*SPHPNT(4,{P1}))
       [IF({P2}.GT.0) [{P6}=0;]
  ]
  ELSE [
       IF({P2}.LT.0) [{P6}=0;]
  ]
}
```

Table 5: Definition of the COMIN/GEOM/

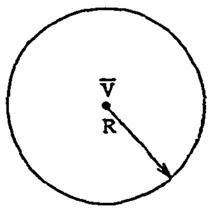
```
"GEOMETRICAL INFORMATION"

REPLACE {;COMIN/GEOM/;} WITH
 {;COMIN/RPPDTA,SPHDTA,RCCDTA,ZONDTA,TVALCG/;}
```

Table 6: Example of system definition of PRESTA-CG

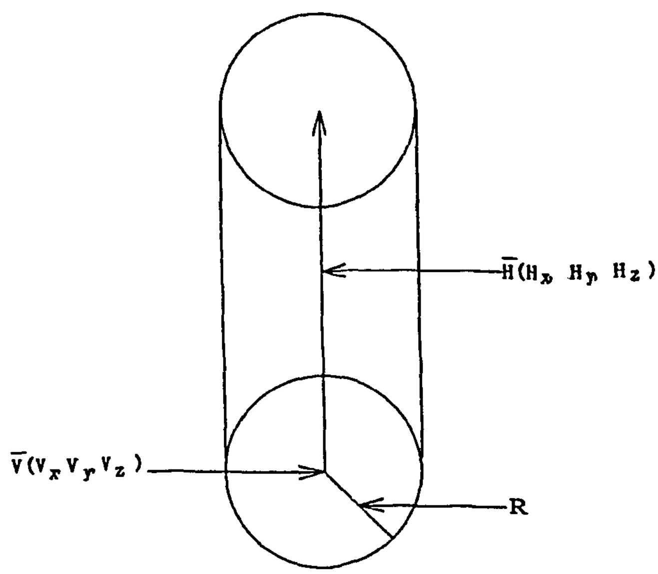
```
*  MATERIAL COUNT    DEP.No.
     3                 3
*  MATERIAL NAME
AIR
ACRYLE
AIR1
*GEOMETRY
*        1         2         3         4         5         6         7
*234567890123456789012345678901234567890
1234567890123456789012345678901
  RCC     0.00      0.00      0.00      0.00      0.00      17.30
          0.235
  RCC     0.00      0.00      3.11      0.00      0.00      11.98
          2.67
  RCC     0.00      0.00      3.11      0.00      0.00      11.98
          3.11
  SPH     0.00      0.00      3.11      2.67
  SPH     0.00      0.00      3.11      3.11
  SPH     0.00      0.00     15.09      2.67
  SPH     0.00      0.00     15.09      3.11
  SPH     0.00      0.00      9.10    100.0
  SPH     0.00      0.00      9.10    200.0
  END
*        1         2         3         4         5         6         7
*234567890123456789012345678901234567890123456789012345678901234567890
* COLLECTING ELECTRODE
   Z1          +1
* GAS(AIR)
   Z2          +2     -10R    +4     -10R    +6     -1
* ACRYLIC
   Z3          +3     -20R    +5     -4      -20R   +7     -6     -2
* AIR
   Z4          +8     -3      -5     -7
* ESCAPE
   Z5          +9     -8
  END
*MET
   2
   3
   2
   1
   0
```



Rectangular Parallelepiped (RPP).



Sphere (SPH).



Right Circular Cylinder (RCC).

Fig.1 Body type in PRESTA-CG

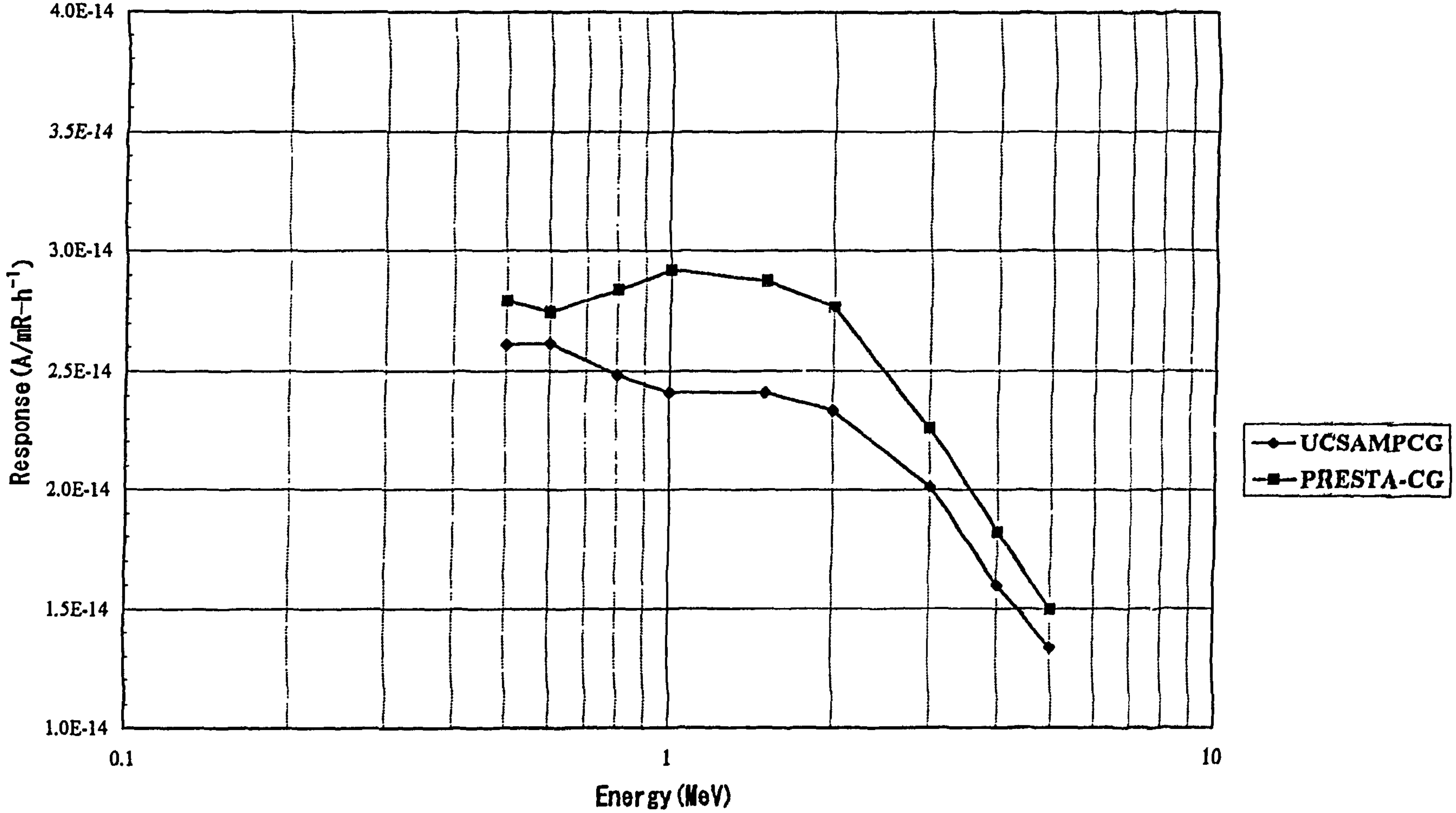


Fig. 2 Comparison of PRESTA-CG and UCSAMPCG

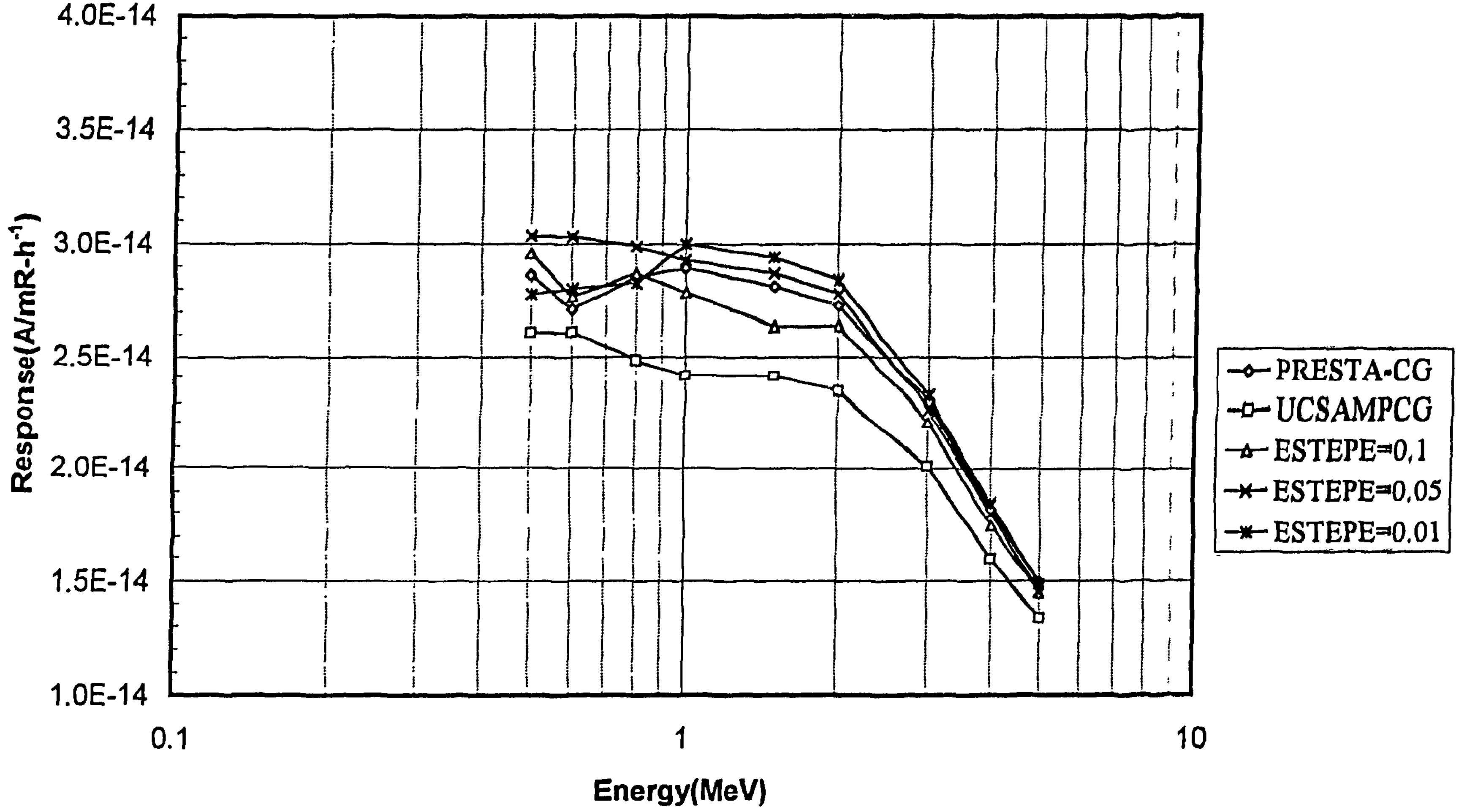


Fig.3 Comparison of PRESTA-CG and UCSAMPCG with ESTEPE