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C*********************************************************************************
C     PROGRAM FOR THE SIMULATION OF THE RESPONSE OF
C     A NAI(TL) SCINTILLATION COUNTER
C     TO PHOTONS OF ENERGY ~ 1 MEV
C     EVALUATE THE MEASURED ENERGY SPECTRUM AND DETECTION EFFICIENCY
C
C     UNITS:
C     ENERGY     MeV
C     LENGHTS  cm
C     ABSORPTION COEFFICIENT FOR NAI : cm-1
C*********************************************************************************
      PROGRAM RIVELATORE
      REAL MASSAEL
      PARAMETER(MASSAEL=0.511)         ! ELECTRON
      COMMON/PAWC/HMEMOR(100000)
      COMMON/PIG/PIG,S
      COMMON/GEOM/RR,H,HR
      COMMON/RISOLU/CC
      COMMON/SIGDAT/EDAT(21),SPHOT(21),SCOMP(21),SPAIR(21),
     &              SCOMPINT,SPHOTINT,STOTINT
C
C
C SET COSTANTS
C
      PIG=4.*ATAN(1.)    ! PI
      DATA BRNA/0.643/   ! MAIN BRANCHING FRACTION FOR SODIUM DECAY
      DATA BRCO/0.5/     ! COBALT DEACYS EQUIPROBABLE
C
C SET OTHER COSTANTS
C
      EMIN=0.01          ! PHOTON MINIMUM ENERGY
C                          (BELOW THIS THRESHOLD THE ENERGY IS ASSUMED
    ABSORBED)
      CC=0.03            ! PARAMETER ENERGY RESOLUTION SIGMA(E)/E= CC/SQRT(E)
      RR=2.55            ! RAGGIO SCINTILLATOR RADIUS
      HR=5.1             ! SCINTILLATOR THICKNESS
C
C
C INITIALIZE  HISTOS
C
      CALL HLIMIT(100000)
      CALL HBOOK1(1,'SPETTRO IN ENERGIA',250,0.,1.5,0.)
      CALL HBOOK1(100,'SPETTRO IN ENERGIA SENZA RISOL',250,0.,1.5,0.)
      CALL HBOOK1(2,'DISTRIBUZIONE COS(TETA)',100,0.,1.,0.)
      CALL HBOOK2(3,'DISTR. PUNTI IMPATTO',100,-3.,3.,100,-3.,3.,0.)
      CALL HBOOK2(4,'COEFF. ASS. FOTOEL (LOG)',100,0.,1.5,100,-5.,3.,0.)
      CALL HBOOK2(5,'COEFF. ASS. COMPTON ',100,0.,1.5,100,0.,1.,0.)
      CALL HBOOK2(6,'COEFF. ASS. TOT.(LOG)',100,0.,1.5,100,-5.,3.,0.)
      CALL HBOOK2(7,'CAMMINO LIBERO',100,0.,1.5,100,0.,20.,0.)
      CALL HBOOK1(8,'DISTR. COS(TETA) COMPTON',100,-1.,1.,0.)
      CALL HBOOK1(9,'DISTR. FI COMPTON',100,0.,7.,0.)
      CALL HBOOK1(10,'DISTR. ELE/E COMPTON',100,0.,1.,0.)
      CALL HBOOK1(11,'DISTR. EGAM/E COMPTON',100,0.,1.,0.)
      CALL HBOOK1(12,'DISTR. PROB.FOTOEL',100,0.,1.,0.)
C
C INITIALIZE COUNTERS AND VARIABLES
      IGAM=0
      NABS=0
      NCOMPT=0
      NFOTO=0
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      NDETECT=0
      S=0.
      SPHOTINT=0.
      SCOMPINT=0.
      STOTINT=0.
C
C
C READ ABSORPTION COEFFICIENTS DATA IN NAI(TL)
C
      OPEN(1,FILE='smudat.dat',STATUS='OLD')
      DO I=1,21
         READ(1,*)EDAT(I),SCOMP(I),SPAIR(I),SPHOT(I)
         PRINT*,'ENERGIA=',EDAT(I),' SCOMP=',SCOMP(I),
     &          ' SPAIR=',SPAIR(I),'SPHOT=',SPHOT(I)
      END DO
      CLOSE(1)
C
C SOME IMPUT PARAMETERS
C
      OPEN(2,FILE='input.dat',STATUS='OLD')
      READ(2,*)H
      READ(2,*)ISOURCE
      READ(2,*)NGAMMAX
      READ(2,*)EMINDETECT
      CLOSE(2)
      PRINT*,'ALTEZZA SORGENTE =',H
      IF(ISOURCE.EQ.1)THEN
         PRINT*,' SORGENTE = SODIO'
      ELSE IF(ISOURCE.EQ.2)THEN
         PRINT*,' SORGENTE = CESIO'
      ELSE IF(ISOURCE.EQ.3)THEN
         PRINT*,' SORGENTE = COBALTO'
      ELSE
         STOP'ERRORE CODICE SORGENTE RADIOATTIVA'
      ENDIF
      PRINT*,'NUMERO FOTONI EMESSI DALLA SORGENTE = ',NGAMMAX
      PRINT*,'ENERGIA MINIMA DI RIVELAZIONE
     & (PER CALC. EFFICIENZA) in MeV = ',EMINDETECT
C
C EVALUATE MAXIMUM ANGLE ACCEPTED BY THE DETECTOR (GEOMETRICAL ACCEPTANCE)
C
      COSTELIM=H/SQRT(RR**2+H**2)

C
C START MAIN LOOP (ON PHOTONS FROM THE SOURCE)
C
      DO 100 J=1,NGAMMAX
C
C SET INITIAL ENERGY LOSS TO ZERO
C
         EPERSA=0.
C
C EXTRACT PHOTON ENERGY ACCORDING TO SELECTED SOURCE
C     IF ISOURCE = 1 SODIUM, = 2 CESIUM, = 3 COBALT
C
         R=RNDM(S)
         IF(ISOURCE.EQ.1)THEN
            IF(R.LT.BRNA)THEN
               E0=0.511
            ELSE
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               E0=1.28
            ENDIF
         ENDIF
         IF(ISOURCE.EQ.2)E0=0.662
         IF(ISOURCE.EQ.3)THEN
            IF(R.LT.BRCO)THEN
               E0=1.17
            ELSE
               E0=1.33
            ENDIF
         ENDIF
C
C SET INITIAL ENERGY OF THE PHOTON FROM THE SOURCE
C
         E=E0
C
C EXTRACT A UNIFORM DIRECTION IN SOLID ANGLE AND WITHIN GEOMETRICAL ACCEPTANCE
C
         CALL ESTRAZIONE(TETA,FI,COSTELIM)
C
C EVALUATE IMPACT POSITION OF THE PHOTON ON THE SCINTILLATOR SURFACE
C
         CALL IMPATTO(X,Y,Z,TETA,FI)
C
C FILL CONTROL HISTOGRAMS
C
         CALL HFILL(2,COS(TETA),0.,1.)
         CALL HFILL(3,X,Y,1.)
C
C-------------------------
C START PHOTON HISTORY
C-------------------------
C CHECK PHOTON ENERGY
C
 20      IF(E.LT.EMIN)THEN
C
C IF PHOTON ENERGY < EMIN IT IS ASSUMED FULLY LOST IN THE SCINTILLATOR
C
C
C SUM LOST ENERGY TO THE TOTAL LOST ENERGY
C
            EPERSA=EPERSA+E
C
C APPLY GAUSSIAN SPREAD DUE TO DETECTOR
C
            CALL RISOL(EMISUR,EPERSA)
C
C FIL HISTOGRAM
C
            IF(EMISUR.GT.0)CALL HFILL(1,EMISUR,0.,1.)
            IF(EPERSA.GT.0)CALL HFILL(100,EPERSA,0.,1.)
C
C INCREASE NUMBER OF DETECTED PHOTONS (ABOVE THRESHOLD EMINDETECT)
C FOR EFFICIENCY EVALUATION
C
            IF(EMISUR.GT.EMINDETECT)NDETECT=NDETECT+1
            GOTO 100
         ELSE
C PHOTON ENERGY > EMIN
C
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C EVALUATE THE FREE PATH ACCORDING TO THE EXPONENTIAL DISTRIBUTION WITH GIVEN
    ABSORPTION COEFFICIENT
C
            CALL NPOSIZIONE(X1,Y1,Z1,X,Y,Z,E,TETA,FI)
C
C ASSIGN NEW POSITION
C
            X=X1
            Y=Y1
            Z=Z1
C
C     CHECK IF THE PHOTON IS IN THE SCINTILLATOR
C
            IPOS=INCILIN(X,Y,Z)
            IF(IPOS.EQ.0)THEN
C
C     PHOTON OUTSIDE THE SCINTILLATOR
C
               CALL RISOL(EMISUR,EPERSA)
               IF(EMISUR.GT.0)CALL HFILL(1,EMISUR,0.,1.)
               IF(EPERSA.GT.0)CALL HFILL(100,EPERSA,0.,1.)
               IF(EMISUR.GT.EMINDETECT)NDETECT=NDETECT+1
               GOTO 100
            ELSE
C
C     PHOTON INSIDE THE SCINTILLATOR
C
C
C EXTRACT TYE OF INTERACYION: PHOTOELECTRIC OR COMPTON
C
               CALL CHOICE(LL)
               IF(LL.EQ.1)THEN
                  NFOTO=NFOTO+1
C
C ASSUME: IF PHOTOELECTRIC THE PHOTON ENERGY IS FULLY LOST IN THE SCINTILLATOR
    AT THE INTERACTION POINT
C (IF NOT: START ELECTRON HISTORY + PHOTON X (OR AUGER ELECTRON))
C
                  EPERSA=EPERSA+E
                  CALL RISOL(EMISUR,EPERSA)
                  IF(EMISUR.GT.0)CALL HFILL(1,EMISUR,0.,1.)
                  IF(EPERSA.GT.0)CALL HFILL(100,EPERSA,0.,1.)
                  IF(EMISUR.GT.EMINDETECT)NDETECT=NDETECT+1
                  GOTO 100
               ELSE
                  NCOMPT=NCOMPT+1
C
C IF COMPTON CALL ROUTINE FOR EXTRACTION OF SCATTERED PHOTON ANGLES
C (TETAF,FIF) AND RECOIL ELECTRON ENERGY (ELE)
C
                  CALL COMPTON(E,ELE,EGAM,TETAF,FIF)
C
C ASSUME:
C KINETIC ENERGY OF THE RECOIL ELECTRON FULLLY DEPOSITED IN THE SCINTILLATOR
    AT THE INTERACTION POINT
C (IF NOT: START ELECTRON HISTORY)
C
                  EPERSA=EPERSA+ELE
C
C ASSIGN NEW DIRECTION AND ENERGY TO THE PHOTON
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C
                  CALL ROTAZIONE(TETAN,FIN,TETA,FI,TETAF,FIF)
                  FI=FIN
                  TETA=TETAN
                  E=EGAM
C
C GO TO BEGINNING OF PHOTON HISTORY
C
                  GOTO 20
               ENDIF
            ENDIF
         ENDIF
 100  CONTINUE
C
C CALL ROUTINE TO WRITE HISTOGRAMS IN A FILE FOR PAW
C
      CALL HRPUT(0,'SPETTRO.PAW','N')
C
C PRINT HISTOGRAMS ON SCREEN
C
C      CALL HPRINT(0)
C
      PRINT*,'NUMERO TOTALE DI INT. COMPTON =',NCOMPT
      PRINT*,'NUMERO TOTALE DI INT. FOTOEL. =',NFOTO
C
C EVALUATE AND PRINT ON SCREEN DETECTION EFFICIENCY
C
      PRINT*,' EFFICIENZA =',FLOAT(NDETECT)/FLOAT(NGAMMAX)
      STOP
      END
C
C
C*************************************************************************
      SUBROUTINE ESTRAZIONE(TETA,FI,COSTELIM)
C
C UNIFORM EXTRACTION OF COS(TETA) BETWEEN COSTELIM AND 1, FI BETWEEN 0 AND
    2PIG
C
      COMMON/PIG/PIG,S
      FI=2*PIG*RNDM(S)
      COSTETA=COSTELIM+RNDM(S)*(1-COSTELIM)
      TETA=ACOS(COSTETA)
      RETURN
      END
C
C*************************************************************************
      SUBROUTINE IMPATTO(X,Y,Z,TETA,FI)
      COMMON/GEOM/RR,H,HR
      X=H*TAN(TETA)*COS(FI)
      Y=H*TAN(TETA)*SIN(FI)
      Z=0.
      RETURN
      END
C
C*************************************************************************
      SUBROUTINE RISOL(EMISUR,EPERSA)
C
C      GAUSSIAN RANDOM NUMBER GENERATOR
C      MEAN = EPERSA; STANDARD DEVIATION = XS
C
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      COMMON/PIG/PIG,S
      COMMON/RISOLU/CC
      V1=0.
C
C EVALUATE SIGMA(E) FROM FORMULA SIGMA(E)/E=CC/SQRT(EPERSA)
C
      XS=CC*SQRT(EPERSA)
C
C EXTRACT 12 UNIFORM RANDOM NUMBER BETWEEN 0 AND 1
C THEIR SUM IS APPROXIMATELY A GAUSSIAN
C CENTRAL LIMIT THEOREM (MEAN = 6  VARIANCE = 1)
C
      DO I=1,12
         V1=V1+RNDM(S)
      END DO
C
      EMISUR=(V1-6.)*XS+EPERSA
C
C CHECK THAT ENERGY AFTER RESOLUTION SPREAD IS NOT NEGATIVE; IF NEGATIVE SET
    IT TO ZERO.
C
      IF(EMISUR.LT.0.)EMISUR=0.
      RETURN
      END
C
C*********************************************************************************
      FUNCTION INCILIN(X,Y,Z)
      COMMON/GEOM/RR,H,HR
      INCILIN=1
      IF(Z.GT.0.AND.Z.LT.HR)THEN
         IF(SQRT(X**2+Y**2).GT.RR)INCILIN=0
         RETURN
      ELSE
         INCILIN=0
         RETURN
      ENDIF
      END
C
C*********************************************************************************
      SUBROUTINE CHOICE(LL)
      COMMON/PAWC/HMEMOR(100000)
      COMMON/PIG/PIG,S
      COMMON/SIGDAT/EDAT(21),SPHOT(21),SCOMP(21),SPAIR(21),
     &              SCOMPINT,SPHOTINT,STOTINT
      PPHOT=SPHOTINT/STOTINT
      IF(RNDM(S).LT.PPHOT)THEN
         LL=1
      ELSE
         LL=2
      ENDIF
C
C     FILL CONTROL HISTOGRAMS
C
         CALL HFILL(12,PPHOT,0.,1.)
      RETURN
      END
C
C*********************************************************************************
      SUBROUTINE NPOSIZIONE(X1,Y1,Z1,X,Y,Z,E,TETA,FI)
      REAL MASSAEL
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      PARAMETER(MASSAEL=0.511)         ! ELECTRON REST MASS
      COMMON/PAWC/HMEMOR(100000)
      COMMON/PIG/PIG,S
      COMMON/SIGDAT/EDAT(21),SPHOT(21),SCOMP(21),SPAIR(21),
     &              SCOMPINT,SPHOTINT,STOTINT
C
C     EVALUATE ABSORPTION COEFFICIENT BY LINEAR INTERPOLATION
C     (ONLY COMPTON AND PHOTOELECTRIC)
C
      DO I=1,20
         IF(E.GT.EDAT(I).AND.E.LT.EDAT(I+1))THEN
            SPHOTINT=((SPHOT(I+1)-SPHOT(I))/(EDAT(I+1)-EDAT(I)))
     &           *(E-EDAT(I)) + SPHOT(I)
            SCOMPINT=((SCOMP(I+1)-SCOMP(I))/(EDAT(I+1)-EDAT(I)))
     &           *(E-EDAT(I)) + SCOMP(I)
         ENDIF
      END DO
      STOTINT=SPHOTINT+SCOMPINT
C
C EXTRACT FREE PATH ACCORDING TO THE EXPONENTIAL DISTRIBUTION WITH GIVEN
    ABSORPTION COEFFICIENT
C
      RO=-LOG(1.-RNDM(S))/STOTINT
C
C FIL CONTROL HISTOGRAMS
C
      CALL HFILL(4,E,LOG(SPHOTINT),1.)
      CALL HFILL(5,E,SCOMPINT,1.)
      CALL HFILL(6,E,LOG(STOTINT),1.)
      CALL HFILL(7,E,RO,1.)
C
C EVALUATE NEW POSITION
C
      X1=X+RO*SIN(TETA)*COS(FI)
      Y1=Y+RO*SIN(TETA)*SIN(FI)
      Z1=Z+RO*COS(TETA)
      RETURN
      END
C
C*********************************************************************
      SUBROUTINE COMPTON(E,ELE,EGAM,TETAF,FIF)
      REAL MASSAEL
      PARAMETER(MASSAEL=0.511)         ! ELECTRON REST MASS
      COMMON/PIG/PIG,S
C
C EXTRACTION OF FI, UNIFORM
C
      FIF=2*PIG*RNDM(S)
C
C EXTRACTION OF TETA, UNIFORM (BEWARE! TETA UNIFORM MEANS F(TETA)->
    F(TETA)*SIN(TETA)),
C ACCORDING  TO THE DIFFERENTIAL COMPTON CROSS SECTION EVALUATED BY KLEIN-
    NISHINA
C USE HIT OR MISS METHOD FOR EXTRACTION OF VARIABLE
C
      SEZMAX=2.
 200  TETAF=PIG*RNDM(S)
      SS=SEZMAX*RNDM(S)
C
C EVALUATE ENERGY OF SCATTERED PHOTON AND RECOLI ELECTRON
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C
      EGAM=E/(1.+(E/MASSAEL)*(1.-COS(TETAF)))
      ELE=E-EGAM
      SEZCOMP=((EGAM/E)+(EGAM/E)**3-((EGAM/E)*SIN(TETAF))**2)
     &        *SIN(TETAF)
      IF(SS.GT.SEZCOMP)THEN
         GOTO 200
      ELSE
C
C     FILL CONTROL HISTOGRAMS
C
         CALL HFILL(8,COS(TETAF),0.,1.)
         CALL HFILL(9,FIF,0.,1.)
         CALL HFILL(10,(ELE/E),0.,1.)
         CALL HFILL(11,(EGAM/E),0.,1.)
         RETURN
      ENDIF
      END
C
C*************************************************************************

      SUBROUTINE ROTAZIONE(TETAN,FIN,TETA,FI,TETAF,FIF)
      COMMON/PIG/PIG,S
      COMMON/PAWC/HMEMOR(100000)
C
C     EVALUATE NEW DIRECTION, TETA AND FI, OF THE SCATTERED PHOTON IN THE
    LABORATORY FRAME SYSTEM
C     USE CERNLIB ROUTINE POLROT(T,F,T1,F1,THAX,PHAX,ROTANG)
C     WITH:
C     T= POLAR ANGLE OLD SYSTEM
C     F= AZIMUT ANGLE OLD SYSTEM
C     T1= POLAR ANGLE NEW ROTATED SYSTEM
C     F1= AZIMUT ANGLE NEW ROTATED SYSTEM
C     THAX,PHAX = ANGLE OF THE ROTATION AXIS IN THE OLD SYSTEM
C     ROTANG = ROTATION ANGLE AROUND THE ROTATION AXIS
C
      THAX1=-TETA
      PHAX1=0.
      ROTANG1=-FI
      CALL POLROT(TETAF,FIF,TETA1,FI1,THAX1,PHAX1,ROTANG1)
      THAX2=PIG/2.
      PHAX2=PIG/2.
      ROTANG2=-TETA
      CALL POLROT(TETA1,FI1,TETAN,FIN,THAX2,PHAX2,ROTANG2)
      RETURN
      END
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