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An Adjoint Gamma-Ray Moments Computer Code, ADJMOM-I

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An Adjoint Gamma–Ray Moments Computer Code, ADJMOM–I

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Table of Contents

An Adjoint Gamma-Ray Moments Computer Code, ADJMOM-I*

George L. Simmons**

In this paper we discuss a computer code for generating spatial-angular moments of the adjoint gamma-ray flux in an infinite medium. The equation for the flux moments is given and techniques used for the solution are described. Details of the input data and a sample problem are also supplied.

Key words: Adjoint; buildup factor; dosimetry; gamma-ray transport; moments method; shielding.

1. Introduction and Theory

This note describes a computer code, ADJMOM-I, which can be used to calculate the moments (spatial and angular) of the adjoint gamma-ray flux distribution in an infinite homogeneous medium. These moments can then be used to calculate dose distributions for monoenergetic point isotropic, plane isotropic, plane oblique, and point conical sources. The adjoint moments method is simply the application of the moments method [1][1] to the adjoint gamma-ray transport equation. A particular feature of the adjoint formulation is that the contribution of annihilating electron pairs and fluorescent gamma-rays to the gamma-ray transport is quite simple to include. Additionally the adjoint source may have delta function angular characteristics thereby allowing the calculation of the dose angular distribution.

The adjoint moments method for gamma-rays has been applied by several authors [2,3,4,5] but only a limited amount of results have been

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[1] Figures in brackets indicate the literature references at the end of this paper.

obtained. In the formulation of the adjoint equation, we begin with the one dimensional gamma-ray transport equation for a plane monoenergetic source located at z = 0 with angular characteristics $S(\vec{\omega})$,

$$\cos\theta \frac{\partial N}{\partial z}(E,z,\vec{\omega}) + \mu(E)N(E,z,\vec{\omega}) = \int_{E}^{E_o} dE' \int_{4\pi} \frac{d\Omega'}{2\pi} K(E,E',\cos\Theta)N(E',z,\vec{\omega}) +$$

$$+ S(\vec{\omega}) \frac{\delta(E-E_o)\delta(z)}{4\pi} + \frac{\delta(E-1)}{2\pi} \int_{2}^{E_o} dE' \int_{4\pi} d\Omega' \mu_{pp}(E')N(E',z,\vec{\omega}') +$$

$$+ \omega_k \frac{\delta(E-E_k)}{4\pi} \int_{E'_k}^{E_o} dE' \int d\Omega' \mu_{ph}(E')N(E',z,\vec{\omega}'). \qquad (1)$$

where the last two terms in the equation represent the contribution of annihilating electron pairs and fluorescent gamma-rays, respectively. Note that electron motion is not considered. In Equation (1)

$N(E,z,\vec{\omega})$ is the photon flux (gammas/sr-sec-cm^2),

E is the photon energy ($m_o c^2$ units),

$\vec{\omega}$ is the photon direction with $\vec{\omega}\cdot\vec{k} = \cos\theta$, when $\vec{k}$ is a unit vector in the positive z direction.

E_o is the source energy,

$\mu(E)$ is the total attenuation coefficient in Thomson units per electron (TU/el), $\mu(cm^2/g) = 0.400594\ (Z/A)\ \mu(TU/el)$,

$\cos\Theta = 1 - \frac{1}{E} + \frac{1}{E'}$,

E' is the initial energy of the gamma ray,

E is the final energy after scattering,

$\mu_{pp}(E)$ is the pair production cross section (TU/electron),

$\mu_{ph}(E)$ is the photoelectric absorption cross section (TU/el),

E_k is the fluorescent yield for K X-rays of energy E_k,

E_k' is the minimum energy for ionizing K electrons,

$K(E,E') = 0.375\ E \left\{\frac{E}{E'} + \frac{E'}{E} + \cos^2\Theta - 1\right\}/(E')^3$.

In developing the equation adjoint to Equation (1), i.e. the forward equation, we note that the forward equation may be simply written as $H\ N = S$, where H is the forward transport operator, N is the flux and S is the source term. The adjoint equation can be represented as $H^{\dagger} N^{\dagger} = S^{\dagger}$, where we use the dagger to indicate the adjoint analogues to the forward equation. If these two equations are to be adjoint, then in operation notation we require

$$(N,\ H^{\dagger} N^{\dagger}) \equiv (N^{\dagger},\ HN). \tag{2a}$$

Clearly, a consequence of this relation is the requirement that

$$(N, S^{\dagger}) = (N^{\dagger}, S)\ . \tag{2b}$$

It is this property of the adjoint flux which makes it useful in calculating dose distributions for many types of sources. That is to say, if we use the product of the energy deposition coefficient, $\mu_{ed}(E)$[8], and photon energy, E, as the adjoint source, the energy deposition distribution for the forward problem may be obtained by performing the integrals indicated in Equation (2b). Particularly if

$$S(E,\vec{\omega},z) = \frac{\delta(E-E_o)\delta(z)}{4\pi}$$

and

$$S^{\dagger}(E,\vec{\omega},z) = \frac{E\mu_{ed}(E)\delta(z)}{4\pi}$$

then

$$D(z) = \int_{0}^{E_o} dE'\ E'\mu_{ed}(E') \int_{4\pi} d\Omega' N(E',z,\vec{\omega}')$$

$$= \int_{0}^{\infty} dE'\ \delta(E'-E_o) \int_{4\pi} d\Omega' N^{\dagger}(E',z,\vec{\omega}') \qquad (2c)$$

It is the property of the adjoint flux which allows the computation of dose distributions for many monoenergetic types.

The derivation of the adjoint transport equation is well known and will not be given here. The reader is referred to Reference [6] for a detailed discussion of the formulation of this equation as well as for an extensive bibliography on the subject. The equation for the adjoint flux for a detector with angular response $R(\vec{\omega})$ is

$$-\cos\theta \frac{\partial}{\partial z} N^{\dagger}(E,z,\vec{\omega}) + \mu(E)N^{\dagger}(E,z,\vec{\omega}) = \int_{0}^{E} dE' \int \frac{d\Omega'}{2\pi} K(E',E,-\cos\Theta) \times$$

$$\times N^{\dagger}(E',z,\vec{\omega}') + E\mu_{ed}(E)\delta(z)R(\vec{\omega}) + \frac{\mu_{pp}(E)}{2\pi} \int_{4\pi} d\Omega'\ N^{\dagger}(1,z,\vec{\omega}') +$$

$$+ \frac{\omega_k \mu_{ph}(E)}{2\pi} \int_{4\pi} d\Omega'\ N^{\dagger}(E_k,z,\vec{\omega}'). \qquad (3)$$

where E_c is the minimum final energy attained by a gamma ray of energy E undergoing a single Compton scattering.

Note that Equation (2c) may be obtained by applying Equation (2a) to Equations (1) and (3), with $R(\vec{\omega}) = S(\vec{\omega}) = 1$.

If we define adjoint moments as

$$N^{\dagger}_{n,\ell,m}(E) = \frac{\mu(E)^n}{4\pi E n!}\left(\frac{4\pi}{2\ell+1}\right)^{\frac{1}{2}} \int_{-\infty}^{\infty} dz\; z^n \int_{4\pi} d\Omega'\; Y_{\ell}^{m*}(\theta,\varphi)\; N^{\dagger}(E,z,-\vec{\omega}), \quad (4)$$

then Equation (3) can be transformed into the following adjoint moments equation

$$\mu(E)N^{\dagger}_{n,\ell,m}(E) = \int_{E_c}^{E} dE' \frac{E'}{E}\, K(E',E)\; P_{\ell}\left(1+\frac{1}{E}-\frac{1}{E'}\right)\left[\frac{\mu(E)}{\mu(E')}\right]^n N^{\dagger}_{n,\ell,m}(E') +$$

$$+ \delta_{no} R_{\ell,m}\mu_{ed}(E) + \frac{(1-\delta_{no})\mu(E)}{2\ell+1}\left\{[(\ell+1)^2-m^2]^{\frac{1}{2}} N^{\dagger}_{n-1,\ell+1,m}(E) +\right.$$

$$\left. + (\ell^2-m^2)^{\frac{1}{2}} N^{\dagger}_{n-1,\ell-1,m}(E)\right\} + 2\delta_{\ell o}\frac{\mu_{pp}(E)}{E}\left[\frac{\mu(E)}{\mu(1)}\right]^n N^{\dagger}_{n,o,o}(1) +$$

$$+ \omega_k\, \delta_{\ell o}\frac{\mu_{ph}(E)}{E}\left[\frac{\mu(E)}{\mu(E_k)}\right]^n N^{\dagger}_{n,o,o}(E_k)\;. \quad (5)$$

where $R_{\ell,m}$ is the spherical harmonic coefficient of the angular response function $R(\vec{\omega})$.

The adjoint moments code ADJMOM-I calculates solutions to equation (5). Whereas in the forward moments solution, the solution procedure starts at $E = E_{max}$ and proceeds downward to some minimum solution energy E_{min}, in the adjoint moments solution, the solution procedure starts with E_{min} (typically 10 keV) and goes upward in energy to some maximum energy E_{max} (typically 15 MeV). The technique used in ADJMOM-I to solve Equation (5) is similar to the one that is used in the neutron moments code, MOMENT-I[7]. It involves the use of Gaussian Quadrature. We want to obtain solutions at N energies logarithemically spaced between

E_{max} and E_{min},

$$E_{min} = E_1 < E_2 < E_3 < \dots < E_{N-1} < E_N = E_{max},$$

where we require that $E_i > \frac{E_{i+1}}{2E_{i+1} + 1}$. To illustrate the use of Gaussian Quadrature, we consider Equation (5), for the m = 0 case and an isotropic detector:

$$\mu(E)N^{\dagger}_{n,\ell}(E) - \int_{E_{i-1}}^{E} dE'\frac{E'}{E}K(E',E)\, P_{\ell}(1+\frac{1}{E}-\frac{1}{E'}) \left[\frac{\mu(E)}{\mu(E')}\right]^n N^{\dagger}_{n,\ell}(E') =$$

$$= \delta_{no}\delta_{\ell o}\, \mu_{ed}(E) + \int_{E_c}^{E_{i-1}} dE'\frac{E'}{E} K(E',E)\, P_{\ell}(1+\frac{1}{E}-\frac{1}{E'}) \left[\frac{\mu(E)}{\mu(E')}\right]^n N^{\dagger}_{n,\ell}(E') +$$

$$+ 2\delta_{\ell o}\frac{\mu_{pp}(E)}{E}\left[\frac{\mu(E)}{\mu(1)}\right]^n N^{\dagger}_{n,o}(1) + \omega_k\, \delta_{\ell o}\frac{\mu_{ph}(E)}{E}\left[\frac{\mu(E)}{\mu(E_1)}\right]^n N^{\dagger}_{n,o}(E_k) +$$

$$+ \frac{(1-\delta_{no})}{2\ell+1}\, \mu(E)\left[(\ell+1)N^{\dagger}_{n-1,\ell+1}(E) + \ell N^{\dagger}_{n-1,\ell-1}(E)\right]. \qquad (6)$$

Since the right hand side of equation (6) does not contain $N^{\dagger}_{n,\ell}(E)$, we set it equal to some known quantity R. We can then rewrite Equation (6) in a more compact form,

$$\frac{R}{\mu(E)} = \int_{E_{i-1}}^{E} \left[\delta(E'-E) - \frac{E'}{E}\frac{K(E',E)}{\mu(E)}\, P_{\ell}(1+\frac{1}{E}-\frac{1}{E'}) \left\{\frac{\mu(E)}{\mu(E')}\right\}^n\right] N^{\dagger}_{n,\ell}(E')dE' \qquad (7)$$

The integral is evaluated by writing the term in square brackets as a sum of two delta functions, namely

$$\delta(E'-E) - \frac{E'}{E}\frac{K(E',E)}{\mu(E)}\, P_{\ell}(1+\frac{1}{E}-\frac{1}{E'})\left[\frac{\mu(E)}{\mu(E')}\right]^n = \alpha_{n\ell}\delta(E'-E_{i-1}) +$$

$$+ \beta_{n\ell}\delta(E'-E^{*}_{n,\ell}) \qquad (8)$$

Equation (7) then becomes

$$\alpha_{n\ell} N^{\dagger}_{n,\ell}(E_{i-1}) + \beta_{n,\ell} N^{\dagger}(E^{*}_{n,\ell}) = \frac{R}{\mu(E)} \qquad (9)$$

This procedure is somewhat different from that of Reference [7] in that a dependence on n has been included. The three parameters $\alpha_{n,\ell}$, $\beta_{n,\ell}$, and $E^{*}_{n,\ell}$ may be determined by requiring that the first three moments of the scattering integral be given correctly,

$$I^{j}_{n,\ell} = \int_{o}^{E-E_{i-1}} (E-E')^{j} \frac{E'}{E} \frac{K(E',E)}{\mu(E)} P_{\ell}\left(1+\frac{1}{E}-\frac{1}{E'}\right)\left[\frac{\mu(E)}{\mu(E')}\right]^{n} d(E-E') \qquad (10)$$

Calculation of the first three moments of the functions on each side of equation (8) yields a system of equations:

$$\delta_{jo} - I^{j}_{n,\ell} = \alpha_{n\ell}(E-E_{i-1})^{j} + \beta_{n,\ell}(E-E^{*}_{n,\ell})^{j}, \quad j = 0,\ 1,\ 2 \qquad (11)$$

After obtaining $\alpha_{n,\ell}$, $\beta_{n,\ell}$ and $E^{*}_{n,\ell}$, Equation (9) can be solved for $N^{\dagger}_{n,\ell}(E^{*}_{n,\ell})$. Generally $E^{*}_{n,\ell}$ is not precisely equal to E and an interpolation must be performed to obtain the solution at E.

An interesting feature of Equation (5) has been pointed out by Morris in Reference [5] for the $n = \ell = 0$ case. If an energy deposition coefficient is defined as

$$\mu_{ed}(E) \equiv \mu(E) - \frac{2}{E}\mu_{pp}(E) - \frac{\omega_k}{E}\mu_{pH}(E) - \int_{E_c}^{E} dE' \frac{E'}{E} K(E',E), \qquad (12)$$

then $N^{\dagger}_{0,0}(E) = 1.0$, for all E. This definition of $\mu_{ed}(E)$ is equivalent to the $\mu_K(E)$ defined by Hubbell [8]. By using this form for $\mu_{ed}(E)$ we have an energy absorption coefficient which is consistent with the energy loses that are contained in the solution of the moments equations.

2. Description of Input

ADJMOM-I is written in FORTRAN-IV and is operational on the UNIVAC-1108, CDC-3600, and IBM-360/75 and 360/91. It requires 40K decimal words and two tape drives, one of which may be a scratch tape or disk. Several cases may be processed at one time with the output from each case being saved on the remaining tape.

The following are the input instructions for ADJMOM-I for the UNIVAC-1108 version. The only difference between the three versions of the code is in the assignment of the input and output units--which may be different at each installation.

3. Input

Card 1 (I5)*

NOUTI Number of energies at which adjoint moments will be punched out.

Card 2 (16F5.0)

(EOUTI(I), I = 1, NOUTI) Energy list for which adjoint moments will be punched out on cards. (MeV)

Card 3 (I1,15A4)

IPROB Problem type, IPROB = 1, Complete case; IPROB = 2, Use previous solution grid; IPROB = 3, Read new solution grid.

(TITLE(I), I = 1, 15) Title card for case.

---

* This is the format for the card or cards.

Card 4 (8I5)

NMUS Number of total cross sections.

NSORS Number of energies for energy deposition coefficient.

LS Maximum angular expansion coefficient used, LS-1 = ℓ_{max}.

MINNO Number of integration points for Equation (11).

MAXNO Number of integration points for scattering integral.

NPXS Number of partial cross sections. Pair production and each fluorescent X-ray are considered to be partial cross section reactions.

KEYIND Normally = 0, KEYIND = 1 causes the calculation of adjoint moments for the energy deposition coefficient in Equation (12) to be bypassed.

NEDI Number of energies for specifying the solution mesh.

Card 5 (3E10.0)

ETOP Maximum energy in the calculation. (MeV)

EBOTM Minimum energy in the calculation. (MeV)

XO Coefficient for converting input cross sections to units of TU/el. (Thomson units per electron)

Card 6 (8E10.0)

(EMUS(I), TABMU(I), I = 1,NMUS) EMUS(I) is the energy in MeV, TABMU(I) is the corresponding total cross section. TABMU usually has units of cm^2/g. The EMUS list must be in descending order.

Card 7 (8E10.0)

(ESORS(I), I = 1, NSORS) Energy list for tabulation of energy deposition coefficients (MeV).

Cards 8, 9, 10, 11, and 12 are required for NPXS 〉 0.

Card 8 (12I5)

(NPART(I), I = 1, NPXS) Number of energies for tabulating the I-th partial cross section.

Card 9 (8E10.0)

(YIELD(I), I = 1, NPXS) Photon yield for each partial cross section. Fluorescent yield for μ_{ph} and 2 for μ_{pp}.

Card 10 (8E10.0)

(ECUT(I), I = 1, NPXS) Lowest energy for each partial cross section, MeV. 1.022 MeV for pair production and edge energy for fluorescent gamma-rays.

Card 11 (8E10.0)

(ESTART(I), I = 1, NPXS) Energy for the gamma-ray produced by I-th partial cross section interaction, MeV.

Card 12 (8E10.0) NPXS of these card sets are required. (I = 1, NPXS)

(EPART(J,I), SIGMA(J,I), J = 1, NPART(I)) EPART is the energy in MeV and SIGMA is the corresponding partial cross section. SIGMA has the same units as TABMU in Card 6.

Card 13 (4I5)

NLO Number of harmonic coefficients of the source angular distribution. 1 for isotropic detector.

LZRO Index of source harmonic when NLO = 1. Otherwise arbitrary.

MZRO Index of azimuthal harmonic. Usually MZRO = 0.

NNL Number of (n,ℓ) combination for which solutions are to be obtained.

Card 14 (4I3,4(I6,3I3))

(N(I), L(I),LINKH(I),LINKL(I), I = 1,NNL) where

N(I) n-index for the I-th moment.

L(I) ℓ-index for the I-th moment.

LINKH(I) I-index for the higher ℓ linkage moment.

LINKL(I) I-index for the lower ℓ linkage moment.

Card 15 (8E10.0)

(CNL(I), I = 1,NLO) Harmonic coefficients of the source angular distribution. For an isotropic source, CNL(1) = 1.0.

Card 16 (4(E10.0,I10))

(ED(I),NED(I), I = 1,NED1)

ED(I) Energy at which the grid of solution energies changes.

NED(I) Number of equally spaced intervals (logarithmically) between ED(I) and ED(I+1).

Cards 1 thru 15 are required for the calculation of adjoint moments for the energy deposition coefficient given by Equation (12). The following cards are required in order to do calculations for additional energy deposition coefficients.

Card 17 (15A4)

(TITLE(I), I = 1,15) Title card for additional calculation.

Card 18 (I5,E10.0)

NSXXX Number of cross sections to be read. If NSXXX $<$ 0, then card 19 must be supplied. Otherwise the cross sections for energy deposition will be assumed to be tabulated at the energy grid of the previous case.

DEN Changes cross sections to units of TU/el.

Card 19 (8E10.0) Not required for NSXXX > 0.

(ESORS(I), I = 1, ABS(NSXXX)) Energly list for tabulation of energy deposition cross section, MeV.

Card 20 (8E10.0)

(STSORS(I), I = 1, ABS(NSXXX)) Energy deposition cross section corresponding to the energy list, ESORS.

If NSXXX = 0, then the code assumes that the next card is a new problem card, i.e. Card 3. When the calculation is completed with the energy deposition coefficients given on Card 20, then the code expects a title card (Card 15) and continues on with Card 16, etc. The code will terminate when it encounters an end of file or the end of a data set, whichever is appropriate for the machine being used.

4. Sample Input and Output

Input data for the calculation of adjoint moments for concrete using μ_K for air taken from Reference [8].

CARD COLUMNS

Card Type	111111111122222222223333333333444444444455555555556666666666777777777778 12345678901234567890123456789012345678901234567890123456789012345678901234567890
1	12
2	1.0 0.80 .662 0.60 0.40 .279 0.20 0.10 0.08 0.06 0.04 0.02
3	1 ADJOINT TEST PROBLEM--ALUMINUM--SKIP CONSISTENT PORTION
4	17 17 4 40 40 0 3
5	1.0 0.01 5.181057
6	1.0 0.0614 0.8 0.0683 0.6 0.0777 0.5 0.0841
6	0.4 0.0922 0.3 0.1030 0.2 0.0120 0.15 0.1340
6	0.1 0.162 0.08 0.189 0.06 0.255 0.05 0.334
6	0.04 0.514 0.03 1.03 0.02 3.24 0.015 7.66
6	0.01 25.8
7	1.0 0.8 0.6 0.5 0.4 0.3 0.2 0.15
7	0.1 0.08 0.06 0.05 0.04 0.03 0.02 0.015
7	0.01
13	1 0 0 10
14	0 0 0 0 1 1 0 1 2 0 2 0 2 2 0 2 3 1 4 3
14	4 0 5 0 3 3 0 4 4 2 7 5 5 1 8 6 6 0 9 0
15	1.00
16	1.0 45 0.10 70 0.01
17	ALUMINUM WITH MU-K (AIR) DETECTOR AS ADJOINT SOURCE
18	17 5.0012
20	0.02797 0.02890 0.02958 0.02971 0.02952 0.02876 0.02677 0.02502
20	0.02338 0.02427 0.03053 0.04062 0.06689 0.1480 0.51200 1.27100
20	4.631

```
IPROB= 1             ADJOINT TEST PROBLEM--ALUMINUM--SKIP CONSISTENT PORTION

 NMJS   NSORS     LS    INNO   MAXNO    NPXS  KEYINO    NE01
  17      17       4     40      40       0      1        3

              1.00000         .01000         5.18106

TOTAL CROSS SECTIONS  ENERGY--SIGMA
  .100+01    .614-01    .800+00    .683-01    .600+00    .777-01    .500+00    .841-01    .400+00    .922-01
  .300+00    .103+00    .200+00    .120+00    .150+00    .134+00    .100+00    .162+00    .800-01    .189+00
  .600-01    .255+00    .500-01    .334+00    .400-01    .514+00    .300-01    .103+01    .200-01    .324+01
  .150-01    .766+01    .100-01    .258+02

TOTAL CROSS SECTIONS  ENERGY--SIGMA
  .196+01    .318+00    .157+01    .354+00    .117+01    .403+00    .978+00    .436+00    .783+00    .478+00
  .587+00    .534+00    .391+00    .622+00    .294+00    .694+00    .196+00    .839+00    .157+00    .979+00
  .117+00    .132+01    .978-01    .173+01    .783-01    .266+01    .587-01    .534+01    .391-01    .168+02
  .294-01    .397+02    .196-01    .134+03

 ENERGIES FOR ENTERING DO E DATA
  .100+01    .800+00    . 00+00    .500+00    .400+00    .300+00    .200+00    .150+00    .100+00    .800-01
  .600-01    .500-01    .400-01    .300-01    .200-01    .150-01    .100-01


  1    0    0    0    0        .00000       .00000       .10000+01
  2    0    1    1    1        .00000       .33333+00    .33333+00
  3    2    0    2    0        .10000+01    .00000       .33333+00
  4    0    2    2    2        .00000       .40000+00    .13333+00
  5    4    3    3    1        .66667+00    .33333+00    .20000+00
  6    5    0    4    0        .10000+01    .00000       .20000+00
  7    0    4    3    3        .00000       .42857+00    .57143-01
  8    7    5    4    2        .60000+00    .40000+00    .11429+00
  9    8    6    5    1        .66667+00    .33333+00    .14286+00
 10    9    0    6    0        .10000+01    .00000       .14286+00


    .1000+01   45
    .1000+00   70
    .1000-01    0
```

I	ENERGY(I) (MC**2)	TOTAL( ) (TU/EL	MU-ED(I) (TU/EL)	I	ENERGY(I) (MC**2)	TOTAL(I) (TU/EL)	MU-ED(I) (TU/EL)	I	ENERGY(I) (MC**2)	TOTAL(I) (TU/EL)	MU-ED(I) (TU/EL)
1	1.956926	.3181 7	.140335	2	1.859311	.325981	.141393	3	1.766566	.334040	.142456
4	1.678447	.342298	.143528	5	1.594724	.350761	.144612	6	1.515176	.359091	.145372
7	1.439597	.367422	.145940	8	1.367788	.375946	.146507	9	1.299561	.384668	.147078
10	1.234737	.393592	.147658	11	1.173146	.402718	.148247	12	1.114628	.411764	.148563
13	1.059028	.421014	.148890	14	1.006203	.430471	.149235	15	.956012	.439915	.149378
16	.908324	.449289	.149264	17	.863016	.458863	.149166	18	.819967	.468642	.149091
19	.779066	.478567	.148986	20	.740205	.488089	.148304	21	.703283	.497801	.147642
22	.668202	.5077 5	.147009	23	.634871	.517807	.146416	24	.603203	.528110	.145872
25	.573114	.5385 1	.145281	26	.544526	.548993	.144635	27	.517364	.559679	.144065
28	.491557	.5705 4	.143584	29	.467038	.581680	.143205	30	.443741	.593003	.142943
31	.421607	.604546	.142814	32	.400576	.616313	.142833	33	.380595	.628430	.143136
34	.361610	.640886	.143729	35	.343573	.653589	.144530	36	.326435	.666543	.145558
37	.310152	.679755	.146832	38	.294681	.693228	.148371	39	.279982	.709797	.153024
40	.266016	.726999	.158342	41	.252747	.744618	.164125	42	.240139	.762665	.170395
43	.228161	.781149	.177178	44	.216780	.800080	.184497	45	.205966	.819471	.192379
46	.195693	.839331	.200846	47	.189360	.858622	.212981	48	.183233	.878357	.225415
49	.177303	.898545	.238462	50	.171566	.919197	.252036	51	.166014	.940324	.266151
52	.160642	.961936	.280818	53	.155444	.986501	.298512	54	.150414	1.020871	.326082
55	.145547	1.056439	.354926	56	.140837	1.093245	.385090	57	.136280	1.131335	.416616
58	.131870	1.170751	.449550	59	.127603	1.211540	.483945	60	.123474	1.253751	.519845
61	.119478	1.297432	.557305	62	.115612	1.351792	.605532	63	.111871	1.419241	.666941
64	.108251	1.490055	.731805	65	.104748	1.564402	.800299	66	.101358	1.642459	.872594
67	.098079	1.724410	.948880	68	.094905	1.835581	1.054479	69	.091834	1.956012	1.169436
70	.088862	2.084345	1.292397	71	.085987	2.221097	1.423066	72	.083204	2.366822	1.564415
73	.080512	2.522108	1.714607	74	.077907	2.693764	1.881274	75	.075386	2.916596	2.099224
76	.072946	3.157862	2.335696	77	.070586	3.419086	2.592236	78	.068302	3.701918	2.870462
79	.066091	4.008147	3.172193	80	.063953	4.339707	3.499329	81	.061883	4.698695	3.854010
82	.059881	5.087379	4.238472	83	.057943	5.537917	4.694991	84	.056068	6.077485	5.220427
85	.054254	6.669623	5.808616	86	.052498	7.319455	6.454608	87	.050800	8.032601	7.163983
88	.049156	8.815229	7.942965	89	.047565	9.674111	8.798207	90	.046026	10.616675	9.737305
91	.044537	11.651073	10.768286	92	.043095	12.786255	11.900105	93	.041701	14.032040	.13.142680
94	.040351	15.399203	14.506628	95	.039046	16.906170	16.010516	96	.037782	18.654040	17.755429
97	.036560	20.582615	19.681100	98	.035377	22.710578	21.806087	99	.034232	25.058548	24.151394
100	.033124	27.649263	26.739476	101	.032052	30.507823	29.595175	102	.031015	33.661923	32.746910
103	.030012	37.142109	36.224645	104	.029040	40.983886	40.063935	105	.028101	45.227091	44.304793
106	.027191	49.909615	48.985024	107	.026311	55.076927	54.150141	108	.025460	60.779237	59.850277
109	.024636	67.071924	66.140837	110	.023839	74.016123	73.082960	111	.023068	81.679272	80.744315
112	.022321	90.135813	89.198835	113	.021599	99.467899	98.528731	114	.020900	109.766159	108.825530
115	.020224	121.130632	120.385306	116	.019569	133.671711	133.671711				

ALUMINUM WITH MU-K (AIR) DETECTOR AS ADJOINT SOURCE
17 5.0012000+00

ENERGIES FOR NEW SOURCE FUNCTIONS

.196+01	.157+01	.117+01	.978+00	.783+00	.587+00	.391+00	.294+00
.196+00	.157+00	.117+00	.978-01	.783-01	.587-01	.391-01	.294-01
.196-01							

DOSE COEFFICIENTS FOR ADJOINT SOURCE

.280-01	.289-01	.296-01	.297-01	.295-01	.288-01	.268-01	.250-01
.234-01	.243-01	.305-01	.406-01	.669-01	.148+00	.512+00	.127+01
.463+01							

I	ENERGY(I) (MC**2)	TOTAL(I) (TU/EL)	MU-ED(I) (TU/EL)	I	ENERGY(I) (MC**2)	TOTAL(I) (TU/EL)	MU-ED(I) (TU/EL)	I	ENERGY(I) (MC**2)	TOTAL(I) (TU/EL)	MU-ED(I) (TU/EL)
1	1.956926	.318117	.139884	2	1.859311	.325981	.140937	3	1.766566	.334040	.141998
4	1.678447	.342298	.143067	5	1.594724	.350761	.144144	6	1.515176	.359091	.144917
7	1.439597	.367422	.145518	8	1.367788	.375946	.146121	9	1.299561	.384668	.146727
10	1.234737	.393592	.147335	11	1.173146	.402718	.147939	12	1.114628	.411764	.148121
13	1.059028	.421014	.148303	14	1.006203	.430471	.148486	15	.956012	.439915	.148487
16	.908324	.449289	.148268	17	.863016	.458863	.148050	18	.819967	.468642	.147833
19	.779066	.478567	.147572	20	.740205	.488089	.146889	21	.703283	.497801	.146209
22	.668202	.507705	.145532	23	.634871	.517807	.144859	24	.603203	.528110	.144188
25	.573114	.538511	.143223	26	.544526	.548993	.141933	27	.517364	.559679	.140655
28	.491557	.570574	.139388	29	.467038	.581680	.138132	30	.443741	.593003	.136888
31	.421607	.604546	.135655	32	.400576	.616313	.134433	33	.380595	.628430	.133005
34	.361610	.640886	.131416	35	.343573	.653589	.129845	36	.326435	.666543	.128293
37	.310152	.679755	.126759	38	.294681	.693228	.125244	39	.279982	.709797	.124145
40	.266016	.726999	.123087	41	.252747	.744618	.122038	42	.240139	.762665	.120999
43	.228161	.781149	.119968	44	.216780	.800080	.118946	45	.205966	.819471	.117933
46	.195693	.839331	.116928	47	.189360	.858622	.117574	48	.183233	.878357	.118223
49	.177303	.898545	.118876	50	.171566	.919197	.119532	51	.166014	.940324	.120193
52	.160642	.961936	.120856	53	.155444	.986501	.122070	54	.150414	1.020871	.125315
55	.145547	1.056439	.128647	56	.140837	1.093245	.132067	57	.136280	1.131335	.135578
58	.131870	1.170751	.139182	59	.127603	1.211540	.142882	60	.123474	1.253751	.146681
61	.119478	1.297432	.150580	62	.115612	1.351792	.156434	63	.111871	1.419241	.164704
64	.108251	1.490055	.173412	65	.104748	1.564402	.182580	66	.101358	1.642459	.192233
67	.098079	1.724410	.202396	68	.094905	1.835581	.217493	69	.091834	1.956012	.234087
70	.088862	2.084345	.251948	71	.085987	2.221097	.271171	72	.083204	2.366822	.291861
73	.080512	2.522108	.314129	74	.077907	2.693764	.338940	75	.075386	2.916596	.371159
76	.072946	3.157862	.406440	77	.070586	3.419086	.445074	78	.068302	3.701918	.487382
79	.066091	4.008147	.533710	80	.063953	4.339707	.584443	81	.061883	4.698695	.639998
82	.059881	5.087379	.700834	83	.057943	5.537917	.770481	84	.056068	6.077485	.852099
85	.054254	6.669623	.942363	86	.052498	7.319455	1.042188	87	.050800	8.032601	1.152588
88	.049156	8.815229	1.274683	89	.047565	9.674111	1.409711	90	.046026	10.616675	1.559043
91	.044537	11.651073	1.724194	92	.043095	12.786255	1.906839	93	.041701	14.032040	2.108833
94	.040351	15.399203	2.332224	95	.039046	16.906170	2.579888	96	.037782	18.654040	2.862540
97	.036560	20.582615	3.176160	98	.035377	22.710578	3.524140	99	.034232	25.058548	3.910245
100	.033124	27.649263	4.338651	101	.032052	30.507823	4.813993	102	.031015	33.661923	5.341414
103	.030012	37.142109	5.926620	104	.029040	40.983886	6.577938	105	.028101	45.227091	7.305414
106	.027191	49.909615	8.113345	107	.026311	55.076927	9.010626	108	.025460	60.779237	10.007142
109	.024636	67.071924	11.113864	110	.023839	74.016123	12.342984	111	.023068	81.679272	13.708036
112	.022321	90.135813	15.224053	113	.021599	99.467899	16.907733	114	.020900	109.766159	18.777615
115	.020224	121.130632	20.854295	116	.019569	133.671711	23.160640				

ADJOINT SOLUTIONS FOR ALL ENERGIES-- L=0 MOMENTS ONLY
ALUMINUM WITH MU-K (AIR) DETECTOR AS ADJOINT SOURCE

N= 0 L= 0

1	9.3015932-01	2	9.2662428-01	3	9.2293172-01	4	9.1906497-01	5	9.1500361-01	6	9.1072775-01
7	9.0624759-01	8	9.0155029-01	9	8.9661017-01	10	8.9140649-01	11	8.8591140-01	12	8.7971779-01
13	8.7326291-01	14	8.6652741-01	15	8.5950755-01	16	8.5221427-01	17	8.4458630-01	18	8.3660579-01
19	8.2825965-01	20	8.1966495-01	21	8.1064340-01	22	8.0115516-01	23	7.9117033-01	24	7,8065581-01
25	7.6920976-01	26	7.5685067-01	27	7.4403692-01	28	7.3076150-01	29	7.1700783-01	30	7.0275928-01
31	6.8800371-01	32	6.7273276-01	33	6.5649871-01	34	6.3948382-01	35	6.2212105-01	36	6.0440235-01
37	5.8631907-01	38	5.6782045-01	39	5.4743644-01	40	5.2699809-01	41	5.0669771-01	42	4.8657321-01
43	4.6664925-01	44	4.4691851-01	45	4.2736286-01	46	4.0800022-01	47	3.9436406-01	48	3.8115523-01
49	3.6836711-01	50	3.5599048-01	51	3.4401125-01	52	3.3241116-01	53	3.2094283-01	54	3.0913759-01
55	2,9799308-01	56	2.8746973-01	57	2.7753544-01	58	2.6816237-01	59	2.5931736-01	60	2.5096640-01
61	2.4307302-01	62	2.3538426-01	63	2.2802836-01	64	2.2128377-01	65	2.1509488-01	66	2.0941031-01
67	2.0418153-01	68	1.9905290-01	69	1.9447211-01	70	1.9039030-01	71	1.8675347-01	72	1.8352420-01
73	1.8066150-01	74	1.7803038-01	75	1.7522279-01	76	1.7284220-01	77	1.7083796-01	78	1.6916828-01
79	1.6779026-01	80	1.6666125-01	81	1.6574872-01	82	1.6503609-01	83	1.6417282-01	84	1.6302354-01
85	1.6210004-01	86	1.6137798-01	87	1.6083610-01	88	1.6045597-01	89	1.6022175-01	90	1.6011912-01
91	1.6013584-01	92	1.6026071-01	93	1.6048258-01	94	1.6078830-01	95	1.6114448-01	96	1.6123152-01
97	1.6139438-01	98	1.6162583-01	99	1.6191998-01	100	1.6227124-01	101	1.6267462-01	102	1.6312593-01
103	1.6362187-01	104	1.6420064-01	105	1.6490341-01	106	1.6564152-01	107	1.6641227-01	108	1.6721341-01
109	1.6804283-01	110	1.6889862-01	111	1.6977908-01	112	1.7068269-01	113	1.7160795-01	114	1.7255216-01
115	1.7322998-01	116	1.7326508-01								

N= 2 L= 0

1	7.4544280-01	2	7.5201155-01	3	7.5848556-01	4	7.6485267-01	5	7.7110826-01	6	7.7691983-01
7	7.8226854-01	8	7.8730936-01	9	7.9203523-01	10	7.9641917-01	11	8.0045241-01	12	8.0368809-01
13	8.0649899-01	14	8.0888411-01	15	8.1060604-01	16	8.1148442-01	17	8.1170049-01	18	8.1123301-01
19	8.1001150-01	20	8.0744383-01	21	8.0386038-01	22	7.9920434-01	23	7.9342929-01	24	7.8649131-01
25	7.7815758-01	26	7.6836896-01	27	7.5733601-01	28	7.4504729-01	29	7.3147155-01	30	7.1657923-01
31	7.0034643-01	32	6.8276473-01	33	6.6377132-01	34	6.4350322-01	35	6.2206493-01	36	5.9942771-01
37	5.7556128-01	38	5.5037665-01	39	5.2493253-01	40	4.9929687-01	41	4.7346782-01	42	4.4747681-01
43	4.2133286-01	44	3.9493683-01	45	3.6814559-01	46	3.4082912-01	47	3.2408024-01	48	3.0783586-01
49	2.9205906-01	50	2.7670228-01	51	2.6168822-01	52	2.4693332-01	53	2.3252041-01	54	2.1943654-01
55	2.0716683-01	56	1.9563834-01	57	1.8478352-01	58	1.7454041-01	59	1.6483271-01	60	1.5556687-01
61	1.4661476-01	62	1.3812606-01	63	1.3054939-01	64	1.2358292-01	65	1.1713492-01	66	1.1109924-01
67	1.0534106-01	68	1.0022738-01	69	9.5699990-02	70	9.1626896-02	71	8.7930139-02	72	8.4549178-02
73	8.1407879-02	74	7.8400751-02	75	7.5679086-02	76	7.3307776-02	77	7.1238601-02	78	6.9432655-02
79	6.7853764-02	80	6.6453381-02	81	6.5191879-02	82	6.4033352-02	83	6.2853774-02	84	6.1700103-02
85	6.0706110-02	86	5.9852615-02	87	5.9123158-02	88	5.8503679-02	89	5.7982136-02	90	5.7547953-02
91	5.7192032-02	92	5.6906215-02	93	5.6682172-02	94	5.6507207-02	95	5.6361551-02	96	5.6151326-02
97	5.5989278-02	98	5.5870483-02	99	5.5790959-02	100	5.5746936-02	101	5.5735133-02	102	5.5752622-02
103	5.5797148-02	104	5.5880446-02	105	5.6015196-02	106	5.6170540-02	107	5.6344751-02	108	5.6536361-02
109	5.6743989-02	110	5.6966421-02	111	5.7202513-02	112	5.7451311-02	113	5.7711838-02	114	5.7982386-02
115	5.8160866-02	116	5.7755027-02								

N= 4 L= 0

1	7.8447744-01	2	7.9769676-01	3	8.1111562-01	4	8.2474045-01	5	8.3860957-01	6	8.5148910-01
7	8.6349231-01	8	8.7530300-01	9	8.8695801-01	10	8.9843682-01	11	9.0976086-01	12	9.1968314-01
13	9.2925972-01	14	9.3853977-01	15	9.4665246-01	16	9.5303228-01	17	9.5860495-01	18	9.6334981-01
19	9.6705040-01	20	9.6738237-01	21	9.6614747-01	22	9.6326225-01	23	9.5865852-01	24	9.5227259-01
25	9.4364890-01	26	9.3255955-01	27	9.1940667-01	28	9.0416208-01	29	8.8676962-01	30	8.6717647-01
31	8.4533522-01	32	8.2122833-01	33	7.9505791-01	34	7.6697696-01	35	7.3684375-01	36	7.0460069-01
37	6.7019210-01	38	6.3352362-01	39	5.9950205-01	40	5.6542703-01	41	5.3095844-01	42	4.9610347-01
43	4.6082703-01	44	4.2495739-01	45	3.8823507-01	46	3.5034455-01	47	3.2978418-01	48	3.0984399-01
49	2.9044053-01	50	2.7146978-01	51	2.5277147-01	52	2.3417758-01	53	2.1618479-01	54	2.0171176-01
55	1.8825436-01	56	1.7570074-01	57	1.6393786-01	58	1.5285634-01	59	1.4232263-01	60	1.3216774-01
61	1.2215691-01	62	1.1292857-01	63	1.0535482-01	64	9.8419238-02	65	9.1985100-02	66	8.5880383-02
67	7.9860764-02	68	7.4978909-02	69	7.0739622-02	70	6.6956084-02	71	6.3539282-02	72	6.0403963-02
73	5.7432292-02	74	5.4484301-02	75	5.2065297-02	76	4.9961434-02	77	4.8126283-02	78	4.6522730-02
79	4.5117333-02	80	4.3869245-02	81	4.2737628-02	82	4.1668026-02	83	4.0575456-02	84	3.9593955-02
85	3.8743195-02	86	3.8006553-02	87	3.7369923-02	88	3.6821351-02	89	3.6350657-02	90	3.5949016-02
91	3.5608851-02	92	3.5323456-02	93	3.5086164-02	94	3.4886397-02	95	3.4703695-02	96	3.4496411-02
97	3.4326097-02	98	3.4188853-02	99	3.4081541-02	100	3.4001196-02	101	3.3945264-02	102	3.3911421-02
103	3.3897887-02	104	3.3911326-02	105	3.3959136-02	106	3.4022245-02	107	3.4099338-02	108	3.4189283-02
109	3.4291025-02	110	3.4403643-02	111	3.4526252-02	112	3.4658130-02	113	3.4798538-02	114	3.4946252-02
115	3.5045584-02	116	3.4653015-02								

N= 6 L= 0

1	8.5078599-01	2	8.7046282-01	3	8.9079054-01	4	9.1181719-01	5	9.3365962-01	6	9.5385043-01
7	9.7265792-01	8	9.9152789-01	9	1.0105684+00	10	1.0297924+00	11	1.0492793+00	12	1.0665689+00
13	1.0837852+00	14	1.1010752+00	15	1.1166465+00	16	1.1293379+00	17	1.1412120+00	18	1.1522658+00
19	1.1620786+00	20	1.1656690+00	21	1.1671029+00	22	1.1662617+00	23	1.1630505+00	24	1.1573785+00
25	1.1483914+00	26	1.1355888+00	27	1.1197609+00	28	1.1008500+00	29	1.0787652+00	30	1.0534197+00
31	1.0247316+00	32	9.9266465-01	33	9.5775081-01	34	9.2018635-01	35	8.7949999-01	36	8.3559293-01
37	7.8837130-01	38	7.3774321-01	39	6.9395422-01	40	6.5041982-01	41	6.0630224-01	42	5.6157698-01
43	5.1614796-01	44	4.6975608-01	45	4.2199510-01	46	3.7233451-01	47	3.4791179-01	48	3.2424298-01
49	3.0118946-01	50	2.7857871-01	51	2.5615146-01	52	2.3363341-01	53	2.1192544-01	54	1.9612686-01
55	1.8155112-01	56	1.6804761-01	57	1.5546172-01	58	1.4363895-01	59	1.3238864-01	60	1.2146137-01
61	1.1049974-01	62	1.0053879-01	63	9.2947872-02	64	8.6036202-02	65	7.9628903-02	66	7.3490459-02
67	6.7253970-02	68	6.2522288-02	69	5.8489840-02	70	5.4920859-02	71	5.1721568-02	72	4.8793118-02
73	4.5985371-02	74	4.3100290-02	75	4.0894215-02	76	3.8982426-02	77	3.7319600-02	78	3.5869784-02
79	3.4601128-02	80	3.3478764-02	81	3.2464064-02	82	3.1493029-02	83	3.0481571-02	84	2.9621363-02
85	2.8875010-02	86	2.8227451-02	87	2.7666004-02	88	2.7179989-02	89	2.6760352-02	90	2.6399311-02
91	2.6090209-02	92	2.5827206-02	93	2.5604674-02	94	2.5413872-02	95	2.5233239-02	96	2.5043808-02
97	2.4885036-02	98	2.4753611-02	99	2.4646884-02	100	2.4562353-02	101	2.4497876-02	102	2.4451493-02
103	2.4421697-02	104	2.4413031-02	105	2.4430715-02	106	2.4460812-02	107	2.4502237-02	108	2.4554053-02
109	2.4615391-02	110	2.4685491-02	111	2.4763622-02	112	2.4849194-02	113	2.4941600-02	114	2.5039891-02
115	2.5107189-02	116	2.4752153-02								

INTERPOLATED MOMENTS AT MONOENERGETIC SOURCES
ALUMINUM WITH MU-K (AIR) DETECTOR AS ADJOINT SOURCE

```
E(MEV)=   1.000  E(MC**2)=   1.957  TOTAL= .318117+00  DOSE= .139884+00  DIRECT=     .439724
 0  0   .9301593+00   1  1   .4464763+00   2  0   .7454428+00   2  2   .2203788+00   3  1   .5376884+00
 4  0   .7844774+00   3  3   .1072226+00   4  2   .3388688+00   5  1   .6322624+00   6  0   .8507860+00

E(MEV)=    .800  E(MC**2)=   1.566  TOTAL= .353745+00  DOSE= .144423+00  DIRECT=     .408268
 0  0   .9134349+00   1  1   .4397546+00   2  0   .7732403+00   2  2   .2156511+00   3  1   .5527852+00
 4  0   .8433346+00   3  3   .1038927+00   4  2   .3433221+00   5  1   .6729090+00   6  0   .9410669+00

E(MEV)=    .662  E(MC**2)=   1.295  TOTAL= .385210+00  DOSE= .146764+00  DIRECT=     .380998
 0  0   .8962830+00   1  1   .4310800+00   2  0   .7923109+00   2  2   .2097657+00   3  1   .5599288+00
 4  0   .8876797+00   3  3   .1000873+00   4  2   .3426243+00   5  1   .6996735+00   6  0   .1011777+01

E(MEV)=    .600  E(MC**2)=   1.174  TOTAL= .402563+00  DOSE= .147928+00  DIRECT=     .367466
 0  0   .8860015+00   1  1   .4253234+00   2  0   .8003863+00   2  2   .2060183+00   3  1   .5617157+00
 4  0   .9095753+00   3  3   .9778213-01   4  2   .3409076+00   5  1   .7118044+00   6  0   .1048960+01

E(MEV)=    .400  E(MC**2)=    .783  TOTAL= .477638+00  DOSE= .147596+00  DIRECT=     .309013
 0  0   .8290155+00   1  1   .3916825+00   2  0   .8101221+00   2  2   .1857453+00   3  1   .5483321+00
 4  0   .9667153+00   3  3   .8625194-01   4  2   .3211525+00   5  1   .7296182+00   6  0   .1161190+01

E(MEV)=    .279  E(MC**2)=    .546  TOTAL= .548441+00  DOSE= .142000+00  DIRECT=     .258916
 0  0   .7574802+00   1  1   .3482946+00   2  0   .7688676+00   2  2   .1616742+00   3  1   .4995899+00
 4  0   .9331244+00   3  3   .7376906-01   4  2   .2837232+00   5  1   .6773000+00   6  0   .1136241+01

E(MEV)=    .200  E(MC**2)=    .391  TOTAL= .621781+00  DOSE= .133783+00  DIRECT=     .215162
 0  0   .6652652+00   1  1   .2956628+00   2  0   .6740279+00   2  2   .1346295+00   3  1   .4212863+00
 4  0   .8091902+00   3  3   .6054551-01   4  2   .2337241+00   5  1   .5670974+00   6  0   .9766046+00

E(MEV)=    .100  E(MC**2)=    .196  TOTAL= .839331+00  DOSE= .116928+00  DIRECT=     .139311
 0  0   .4080004+00   1  1   .1655111+00   2  0   .3408293+00   2  2   .7251487-01   3  1   .2010388+00
 4  0   .3503448+00   3  3   .3200693-01   4  2   .1092809+00   5  1   .2362071+00   6  0   .3723348+00

E(MEV)=    .080  E(MC**2)=    .157  TOTAL= .981135+00  DOSE= .121806+00  DIRECT=     .124149
 0  0   .3233917+00   1  1   .1260858+00   2  0   .2355980+00   2  2   .5460314-01   3  1   .1373500+00
 4  0   .2200268+00   3  3   .2396956-01   4  2   .7516022-01   5  1   .1481498+00   6  0   .2165608+00

E(MEV)=    .060  E(MC**2)=    .117  TOTAL= .132593+01  DOSE= .153651+00  DIRECT=     .115882
 0  0   .2389711+00   1  1   .8842998-01   2  0   .1420861+00   2  2   .3747006-01   3  1   .8222843-01
 4  0   .1172337+00   3  3   .1632625-01   4  2   .4525368-01   5  1   .7921132-01   6  0   .1051857+00

E(MEV)=    .040  E(MC**2)=    .078  TOTAL= .266830+01  DOSE= .335244+00  DIRECT=     .125639
 0  0   .1784045+00   1  1   .6207335-01   2  0   .7882836-01   2  2   .2554569-01   3  1   .4592844-01
 4  0   .5490350-01   3  3   .1102768-01   4  2   .2570492-01   5  1   .3777836-01   6  0   .4351054-01

E(MEV)=    .020  E(MC**2)=    .039  TOTAL= .167927+02  DOSE= .256118+01  DIRECT=     .152517
 0  0   .1611192+00   1  1   .5393671-01   2  0   .5637190-01   2  2   .2167714-01   3  1   .3347566-01
 4  0   .3471667-01   3  3   .9297572-02   4  2   .1905338-01   5  1   .2448446-01   6  0   .2524607-01
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15. SUPPLEMENTARY NOTES

16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

In this paper we discuss a computer code for generating spatial-angular moments of the adjoint gamma-ray flux in an infinite medium. The equation for the flux moments is given and techniques used for the solution are described. Details of the input data and a sample problem are also supplied.

17. KEY WORDS (Alphabetical order, separated by semicolons)

Adjoint; buildup factor; dosimetry; gamma-ray transport; moment methods; shielding.

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