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Author

Krane, K.S.

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K. S. Krane

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SOLID-ANGLE CORRECTION FACTORS FOR "FIVE-SIDED" COAXIAL Ge(Li) DETECTORS*

K. S. Krane

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

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Abstract

A previous method for the calculation of solid-angle correction factors of coaxial Ge(Li) detectors is extended to "five-sided" coaxial detectors, and typical results are presented.

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In a previous publication$^{1)}$ the author presented a computer code for the calculation of the solid-angle correction factors for coaxial Ge(Li) detectors. These correction factors Q_k are necessary to correct γ-ray angular distribution and correlation results for the finite solid angles subtended by the radiation detectors. In the present work an extension of the previous calculation for "five-sided" Ge(Li) detectors is described.

A typical "five-sided" coaxial detector is shown in fig. 1. The cross-hatched "active" area is obtained by drifting the lithium not only radially but also from one of the faces. (The cross-section of the detector as seen by the source is assumed to be that of a right-circular cylinder.) The major effects of the extra Li-drift are: (1) the non-active p-type core extends only part of the way through the detector, thus increasing the active volume, and (2) a non-active n-type layer of thickness d is introduced on the front face of the detector.

Whereas in the previous case, the integration involved in the computation of J_k (where $Q_k = J_k/J_o$ in the notation of ref. 1) could be subdivided into three regions, in the present case four regions must be employed, and the path lengths $\chi(\beta)$ are given as follows (with $H = D + d$):

$$\text{I)}\quad 0 \leqslant \beta \leqslant \arctan\left(\frac{r}{H+L}\right), \quad \chi(\beta) = \frac{L - \ell}{\cos\beta}$$

$$\text{II)}\quad \arctan\left(\frac{r}{H+L}\right) \leqslant \beta \leqslant \arctan\left(\frac{r}{H+L-\ell}\right), \quad \chi(\beta) = \frac{H + 2L - \ell}{\cos\beta} - \frac{r}{\sin\beta}$$

$$\text{III)}\quad \arctan\left(\frac{r}{H+L-\ell}\right) \leqslant \beta \leqslant \arctan\left(\frac{R}{H+L}\right), \quad \chi(\beta) = \frac{L}{\cos\beta}$$

$$\text{IV)}\quad \arctan\left(\frac{R}{H+L}\right) \leqslant \beta \leqslant \arctan\left(\frac{R}{H}\right), \quad \chi(\beta) = \frac{R}{\sin\beta} - \frac{H}{\cos\beta}$$

In region II a correction is necessary to compensate for the portion of the path length which passes through the non-active core of the detector, and for all regions, the attenuation of the γ-rays upon passage through the non-active frontal n-layer must be considered.

The computer code modified for this geometry is presented in the Appendix.

Results for the Q_k for a typical detector are given in Table 1, and are compared with the results of the previous calculation for a true coaxial detector of the same dimension (i.e., $\ell = L$, $d = 0$). Two effects can be noted: (1) The Q_k values for the "five-sided" detector are closer to unity than for the true coaxial detector; this results primarily from the "compactness" of the former, since it has less surface area per unit volume. (2) The "five-sided" detector has a smaller absolute efficiency (efficiency $\approx \frac{1}{2} J_o$) for low energy γ-rays, resulting from the attenuation in the frontal non-active layer. (In passing through 1 mm of Ge, a 100-keV γ-ray loses 23% of its intensity.) Owing to this attenuation, a true coaxial detector has efficiency superior to either that of a five-sided coaxial or a planar detector for low-energy γ-rays. However, for all energies, the "five-sided" detector shows a superior peak-to-Compton ratio, since there is less surface area through which the Compton-scattered photons can escape.

Finally, we note that the present method of calculation with the attenuation in the frontal n-region neglected gives results in excellent agreement with the extensive tabulation of Camp and Van Lehn[2]). For an n-layer of thickness 1 mm, the values tabulated in ref. 2 for Q_2 and Q_4 must be reduced by approximately 0.1% and 0.4%, respectively, for γ-rays of energy 50-200 keV. For higher energy γ-rays the corrections become negligibly small.

References

1. K. S. Krane, Nucl. Instr. Methods 98 (1972) 205.
2. D. C. Camp and A. L. Van Lehn, Nucl. Instr. Methods 76 (1969) 192.

Table 1. Solid-angle correction factors Q_k for "five-sided" coaxial detector of dimensions L = 5 cm, R = 2 cm, r = 0.5 cm, ℓ = 3 cm, d = 0.1 cm, D = 5 cm. Frontal area = 12.6 cm^2, Active volume = 60.5 cm^3.

γ-ray energy (keV)	J_o	Q_2	Q_4
100	0.0463 (0.0593)	0.9075 (0.8991)	0.7135 (0.6886)
300	0.0245 (0.0246)	0.9309 (0.9258)	0.7828 (0.7672)
1000	0.0047 (0.0047)	0.9354 (0.9309)	0.7964 (0.7827)

(Values in parentheses are corresponding results for a true coaxial detector of the same dimensions.)

Figure Caption

Fig. 1. Cross-section of "five-sided" coaxial detector.

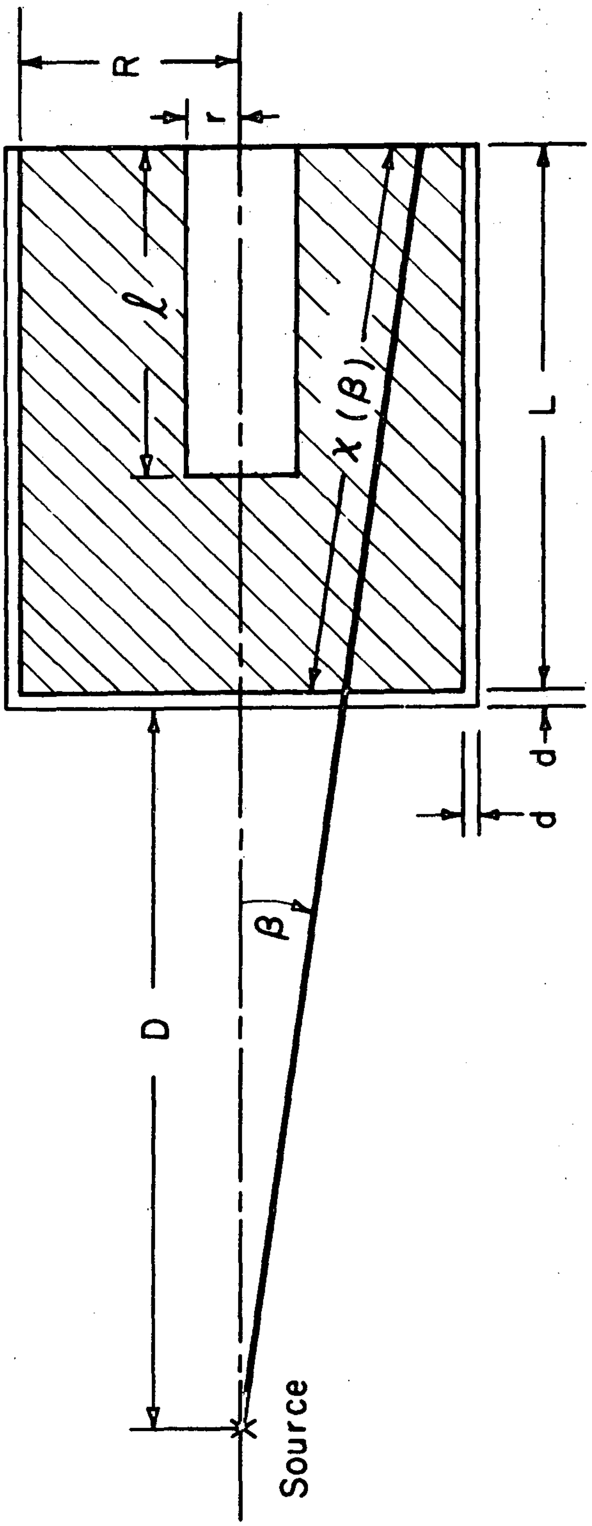

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Fig. 1

Appendix

Below is presented that portion of the computer code for the calculation of the Q_k for "five-sided" coaxial detector which replaces the corresponding portion of the code given in ref. 1. The additional input parameters are: AL = ℓ and DD = d (dimensions defined in fig. 1).

```
    SUBROUTINE GCF(XL,R,A,D,AL,DD,TAU,K,Q)
    DIMENSION F(101),B(5),XJ(2)
    H = D + DD
    B(1) = 0.0
    B(2) = ATAN2(A,H+XL)
    B(3) = ATAN2(A,H+XL-AL)
    B(4) = ATAN2(R,H+XL)
    B(5) = ATAN2(R,H)
    DO 100 N = 1,2
    XJ(N) = 0.0
    IF(K.EQ.0.AND.N.EQ.2) GO TO 110
    KA = K*(2-N) + 1
    DO 100 J = 1,4
    YL = B(J)
    YU = B(J+1)
    DL = (YU - YL)/100.
    DO 90 M = 1,101
    XM = YL + DL*(M-1)
    GO TO (5,10,20,30),J
  5 EX = -TAU*(XL-AL)/COS(XM)
    GO TO 40
 10 EX = TAU*(A-(H+2.*XL-AL)*TAN(XM))/SIN(XM)
    GO TO 40
 20 EX = -TAU*XL/COS(XM)
    GO TO 40
 30 EX = TAU*(H*TAN(XM)-R)/SIN(XM)
 40 F(M) = SIN(XM)*(1.-EXP(EX))*EXP(-TAU*DD/COS(XM))
    IF(J.EQ.2) F(M) = F(M)*EXP(-TAU*(A/SIN(XM) - (H+XL-AL)/COS(XM)))
    GO TO (90,50,60,70,80),KA
    .
    .
    .
```

(Same as in ref. 1).

TECHNICAL INFORMATION DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720