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PENETRATION EFFECTS IN MULTIHOLE COLLIMATORS

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ABSTRACT

Penetration factors in multihole focusing collimators are calculated when plane sources of gamma rays are used. The dependence of these factors on the gamma ray energy is studied and the present theoretical results are compared to the available experimental data.

INTRODUCTION

The total penetration factor of the multihole collimator is the sum of the penetration through the septa and the penetration through the corners of the collimator. Penetration through the septa has been calculated by several authors (Beck 1964 and Rotenberg and Johns 1965), while penetration through the corners has been treated by Rotenberg and Johns (1965) and El-Sayed et al.(1982). In the last treatments, several approximations have been made and the theoretical equations they have reached did not show the dependence of these factors on the hole radius.

Recently, El-Kazzaz and Bishara (1988) have derived some exact expressions for the penetration factors through the corners of focusing collimators. These expressions are modifications to the approach used by Rotenberg and Johns (1965).

The aim of the present work is to calculate the values of the total penetration factors of multihole focusing collimators at different gamma energies making use of the exact expressions for the penetration through corners. Also, to compare the present calculated values to the available experimental data for the 9-holes and 16-holes collimators used by Rotenberg and Johns (1965).

Calculation of the total penetration factors

The total penetration factor, P, for a multihole focusing collimator is given by (Rotenberg and Johns 1965)

$$P = P_{sep.} + P_{cor.} \qquad (1)$$

where $P_{sep.}$ and $P_{cor.}$ are the penetration factors of the gamma rays passing through the septa and through the corners of the collimators respectively.

Penetration through the septa of the multihole collimator is given by (Beck 1964)

$$P_{sep.} = (E_H - E) \; M/E \qquad (2)$$

where E is the geometrical efficiency of the collimator, E_H is the geometrical efficiency of the large hexagonal hole which would be formed if all the septum material were removed or were transparent to gamma rays and M is the mean probability of septum penetration for the gamma rays emitted from a uniform sheet distribution. Expressions for E , E_H and M are given by Beck (1964).

Penetration through the corners of a focusing collimator, $P_{cor.}$, is given by (Rotenberg and Johns 1965)

$$P_{cor.} = P_f + P_b + P_f\, P_b \tag{3}$$

where P_f and P_b are the penetration factors through the front and back corners of the collimator respectively. For a collimator of length L and focal length F, the value of $P_{cor.}$ given by the same authors is

$$P_{cor.} = (2/\mu L)\ [2+(\ (L/F)^2/\ (1+L/F))] + (4/\mu^2 L^2) \tag{4}$$

where μ is the linear absorption coefficient of the collimator material at the gamma energy used.

El-Sayed et al (1982) have modified expression (4) by adding some extra terms in their expansion and have reached the following equation

$$P_{cor.} = (1\text{-exp-}2)\ (2/\mu L)\ [2 + (\ (L/F)^2/\ (1 + L/F)\ )] + (4/u^2L^2)\ [1\text{-}2(\text{exp-}2) + (\text{exp-}4)] \quad (5)$$

In the derivation of equations 4 and 5, several approximations have been made and the equations did not show the dependence of $P_{cor.}$ on the radius of the collimators hole.

El-Kazzaz and Bishara (1988) have applied a similar approach like that used by the above authors, but they abandoned all the approximations used before, thus they have arrived to the following exact expressions for P_f and P_b

$$P_f = (\ (C_1/C)\ -1) + (\mu/CF^2) \int_{x=o}^{x=2/\mu} [1-(\ (L-x)/(\ (L-x)^2 + R^2)^{\frac{1}{2}})].\ (F+x)^2\ .\ (\text{exp-}\mu x).dx \quad (6)$$

and

$$P_b = (\ (C_2/C)-1) + (\mu/C) \int_{x=o}^{x=2/\mu} [1-(\ (L-x)/(\ (L-x)^2 + R^2(1-\ x/L+F)^{2\ \frac{1}{2}})\ ].\ (\text{exp-}\mu x).dx \quad (7)$$

where

$$C = [1\ -(L/\ (L^2 + R^2)^{\frac{1}{2}})\ ]$$

$$C_1 = [1\ -\ (\ (L-\ 2/\mu)/(\ (L-\ 2/\mu)^2 + R^2)^{\frac{1}{2}})]\ (1\ +2/\mu F)^2\ (\exp\ -2)$$

$$C_2 = [1 - ((L - 2/\mu) / ((L - 2/\mu)^2 + R^2(1 - 2/\mu(L+F))^2)^{\frac{1}{2}}]$$

(exp - 2)

R = bigger hole radius

Equation 6 and 7 can be solved numerically by the computer and the values of $P_{cor.}$ may be obtained from equation 3.

RESULTS AND DISCUSSION

Equations 3,6 and 7 are used to calculate the values of $P_{cor.}$ at different gamma energies, for the 9-holes and 16-holes collimators used by Rotenberg and Johns (1965). These results are shown in figure 1, compared to the corresponding values obtained by other authors. Scince the radii of the holes of the two collimators are very close to each other, there is no appreciable difference in the values of $P_{cor.}$ for them.

Adding the values of $P_{cor.}$ obtained from equations 3 , 6 and 7 to the values of $P_{sep.}$ taken from the work of Rotenberg and Johns (1965), one gets the total penetration factors for the two multihole collimators. Figure 2 shows the present theoretical calculations compared to the theoretical and experimental results obtained before. It is clear from the figure that the present calculations are in good agreement with the available experimental data especially at large gamma ray energies. This good fit gives an added support to the expressions derived by the present authors for the penetration factors through the corners of the collimators.

CONCLUSION

The total penetration factors of multihole focusing collimators are calculated at the different gamma ray energies emitted from an extended plane gamma source. These calculations take into consideration the exact expressions, for the penetration through the corner of the collimators, which have been derived before by the present authors. The present calculations are in good agreement with the available experimental data.

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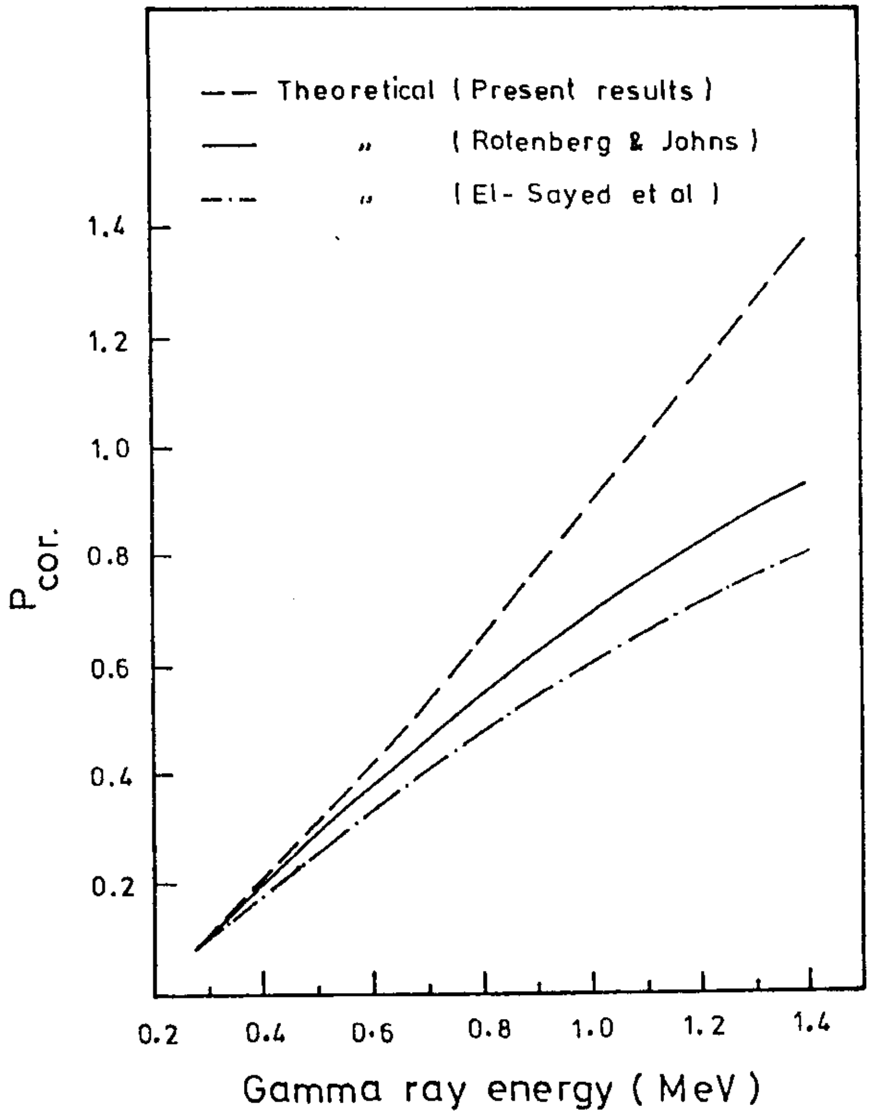

Fig. 1 Values of $P_{cor.}$ at different gamma energies.

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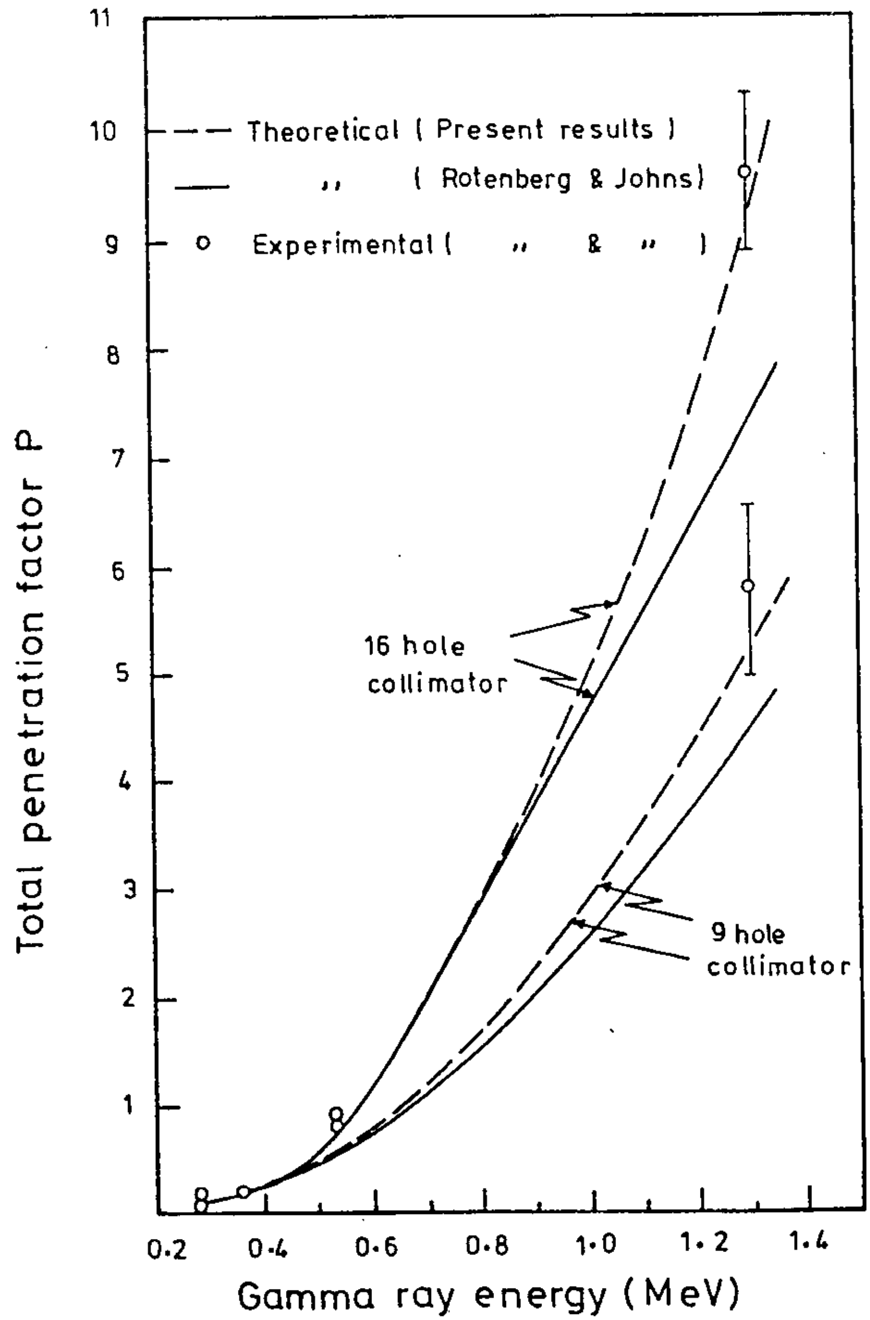

Fig. 2 Comparison of the present theoretical calculations of the total penetration factors to the available experimental data.

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تأثيرات النفاذ فى المسددات متعددة القنوات

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تم فى هذا البحث حساب معاملات النفاذ للمسددات البؤرية متعددة القنوات عند استخدام مصادر ممتدة مستوية لاشعة جاما - ولقد درس اعتماد هذه المعاملات على طاقة أشعة جاما المستخدمة ، كما قورنت النتائج النظرية التى حصل عليها مع النتائج العملية المتاحة والمقاسة بواسطة باحثون اخرون.