ABOUT THE CALCULATION OF BREMSSTRAHLUNG OUTSIDE OF ACCELERATOR BUILDINGS

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1. INTRODUCTION

In the last years in science and engineering the application of accelerators obtained increasing importance because of the growth of their capacity. In order to enlarge the capacity of an existing accelerator it is often necessary to construct shieldings around the original accelerator building. Whereas the enlargement of the thickness of the surrounding walls is not very difficult a special consideration must be given to the shielding properties of the roof. In this connection the radiation skyshine is of interest, because it is hardly possible also to enlarge the thickness of the roof. In this paper the calculation of bremsstrahlung skyshine outside of an accelerator building is described.

2. THE MODEL OF RADIATION TRANSPORT

For the calculation it was assumed that, firstly, for a distance of 1 m from the target the energy and angular distribution of the exposure rate of the arising bremsstrahlung is given according to Fig. 1 and, secondly, that the radiation is totally absorbed in the surrounding walls and is not influenced by the roof.

The geometry of the accelerator building shows Fig. 2. The points for which the exposure rate due to bremsstrahlung skyshine must be calculated are marked by P_1, P_2, ... with the coordinates (x_1, x_2, ...; $y = h_2$; $z = 0$).

Calculations were carried out by means of the Monte-Carlo method. Only such photons are taken into account which are emitted by the target in direction of the roof. The number $N_{E\theta}$ of histories of these photons per energy and angular interval is calculated according to

$$N_{E\theta} \sim \varphi_{E\theta} \sim \dot{X}_{E\theta}(E,\theta)/E\,\mu(E),$$

with $\mu(E)$ as the linear energy transfer coefficient for air and $\varphi_{E\Theta}$ as the flux density per energy and angular interval. Simultaneously for all points P_1, P_2, ... the differential flux density φ_E, the total flux density φ and the total exposure rate $\dot{X}$ are calculated using well-known steps of Monte-Carlo calculations. More details of the model used are given in separate papers (3,4).

3. RESULTS

Some results of the Monte-Carlo calculations of bremsstrahlung exposure rate are shown in Fig. 3. A comparison between Monte-Carlo results and those bei calculation of the single scattered radiation is given in Fig. 4. Note that the Monte-Carlo method is more favourable to obtain differential quantities of the scatterd bremsstrahlung and to obtain results for larger distances between accelerator building and the point of interest. The single-scattering method, on the contrary, represents a relative simple procedure to get approximative values. Variations of the criteria of history termination show that the cut-off energy should be much less than 100 keV (in these calculations 25 keV). The results of such calculations allow the determination of the maximum electron current of the accelerator for which one can ensure radiation protection outside the building.

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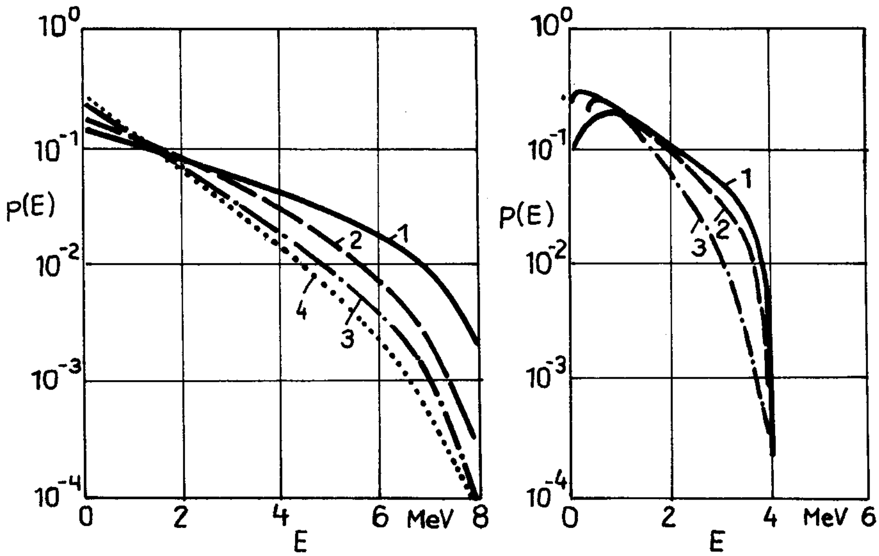

FIG. 1. Energy distribution p(E) of $\dot{X}_{EO}(E,O)$ for several angles O between the direction of the electron beam and the arising bremsstrahlung for a distance of 1 m from the target (1,2)

a) Sn target,
energy of electrons 8 MeV

1 - $0° \leq \theta < 20°$
2 - $20° \leq \theta < 50°$
3 - $50° \leq \theta < 100°$
4 - $100° \leq \theta < 150°$

b) Au target,
energy of electrons 4 MeV

1 - $0° \leq \theta < 10°$
2 - $30° \leq \theta < 60°$
3 - $120° \leq \theta < 150°$

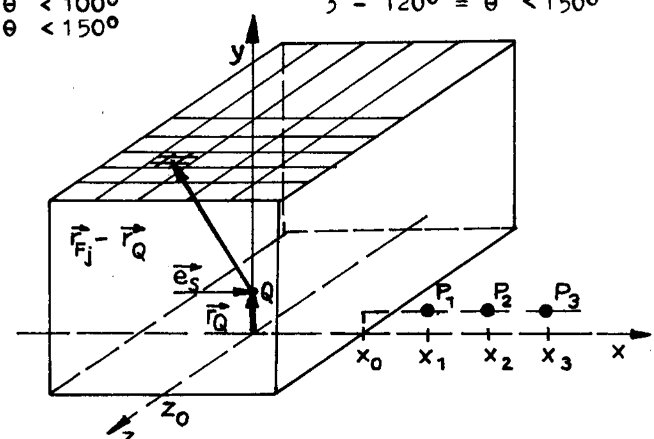

FIG. 2. Geometry of the accelerator building

$\vec{e}_s$ - direction of the electron beam

Q - target, source of bremsstrahlung in the height h_1 (vector $\vec{r}_Q$)

$\vec{r}_{F_j}$ - vector to the centre of the roof square no. j

P_i - points in the height h_2, for which the exposure rate due to bremsstrahlung must be calculated

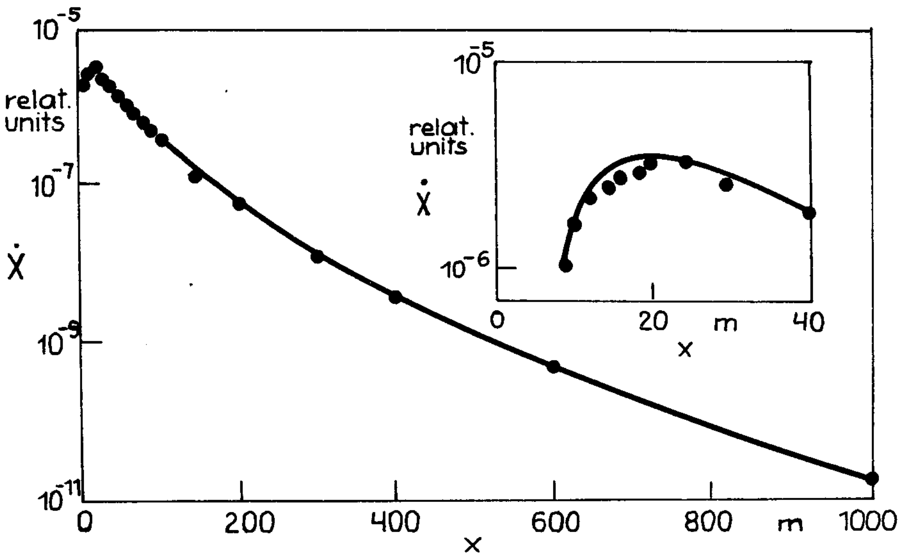

FIG. 3. Exposure rate $\dot{X}$ at several distances x from the target (3)
Sn target, energy of electrons 8 MeV, h_2 = 1 m, z_o = 9 m

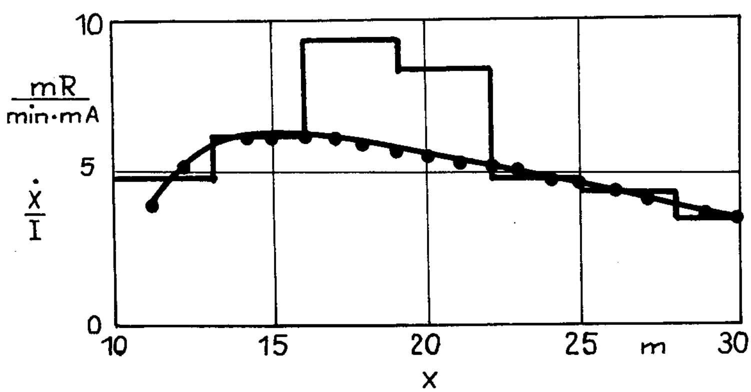

FIG. 4. Exposure rate $\dot{X}$ per electron current I at several distances x from the target (4)

1 - results of Monte-Carlo calculations
2 - results of calculations of the single scatterd radiation

Ta-W-Au target, energy of electrons 2 MeV, h_2 = 1 m, z_o = 25 m