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SHIELDING DESIGN CALCULATION FOR SPring-8 INSERTION DEVICE BEAMLINE

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1. INTRODUCTION

SPring-8, an 8 GeV class synchrotron radiation facility of Japan, is now under construction and the beamlines are in the design stage. The first beam will be emmited by October in 1997. The SPring-8 is composed of an electron/positron linear accelerator (linac), a booster synchrotron injector, and a storage ring (Fig.1). The linac is about 140 m long and accelerates electrons (meaning electrons and positrons) to 1 GeV. The booster synchrotron of which circumference is about 400 m, accelerates the electrons from the linac up to 8 GeV. The electrons are then injected into the storage ring, which is capable of storing circulating currents up to 100 mA at 8 GeV. The circumference of the storage ring is about 1500 m with 38 straight sections including 34 standard ones of 19 m in length and the 4 long ones of 40 m in length. The electrons emit synchrotron radiation while they are being deflected in the fields of the ring bending magnets or specially arranged magnets called insertion devices which are placed in the straight sections. The synchrotron radiation is introduced to an experimental floor by a beamline through ratchet-shaped bulk shielding walls of the storage ring as illustrated in Fig.1. Synchrotron radiation extremely high brilliance and high power density is available at the SPring-8 and

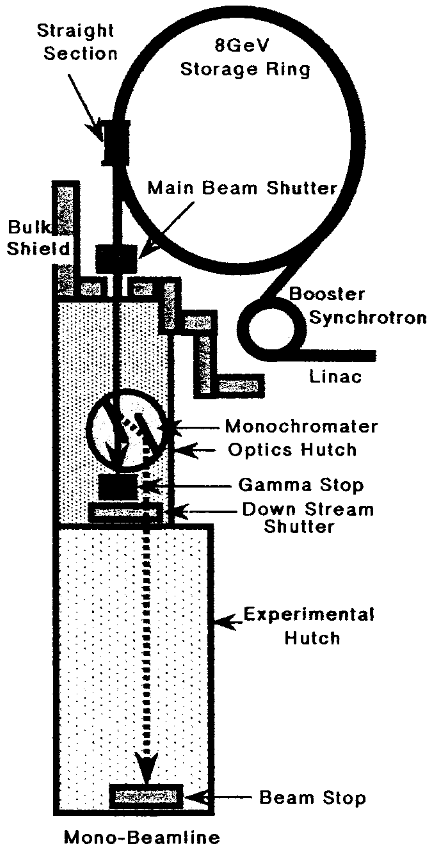

Fig.1 Illustration of the Spring-8 insertion device beamline for monochromatic beams.

therefore the shield of the beamlines for radiation safety must be designed under severe conditions.

The design criteria of 6.67μSv/h and 2.0 μSv/h are employed in occupied areas and at the boundary of controlled area.

Main shielding components for the beamline safety are a main beam shutter, down stream shutter, gamma stop, beam stop, and optics and experimental hutches. In the present paper, we will focus on the calculation for the beam shutter, the gas bremsstrahlung gamma stop and the hutch wall. In the calculation, the following 4 kinds of radiation sources were considered; (a) neutrons, photons and muons due to electron beam loss, (b)synchrotron radiation, (c)bremsstrahlung from the residual-gas molecules in the straight section of the storage ring and (d) photoneutrons generated at the gamma stop struck by gas bremsstrahlung. In this paper, we consider the monochromatic beamline as illustrated in Fig.1.

2. SHUTTER

Optimum thickness of the main beam shutter was calculated by using a modified Jenkin's formula(1) for neutrons and photons and a Swanson's formula(2) for muons. Gas bremsstrahlung calculation was also performed with tabulated data(3). As a results, we found that the tungsten of 18 cm thick or more are necessary on the standard sections. For the down stream shutter, the thickness was calculated by using STAC8, a shielding design code for synchrotron radiation(4). The beam stops are the same as the down stream shutter except for the mechanical movement.

3. HUTCH

One of the functions of the hutch is to shield the scattered photons of synchrotron radiation. Therefore, the structure of hutch depends strongly on the source. The thickness was calculated by using STAC8 as functions of a scattering angle and polarization.

In case of a high-energy inelastic scattering wiggler beamline(5), the key parameters are as fallows; the total power of 18.0 kW, the period length of 12 cm, the peak magnetic fields of 1 T, the period of 37 and the critical energy of 42.7 keV. The shield wall composed of a lead plate of 30 mm thick and an iron plate of 10 mm thick were found to be required for the side wall of the optics hutch including a local shield at 2 m distance from the beam.

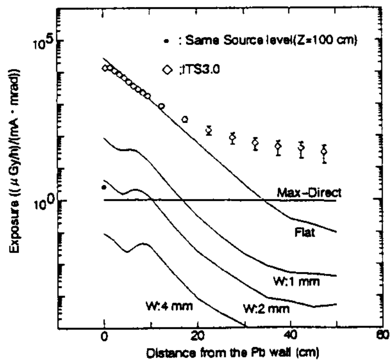

Fig.2 Dose distribution due to ground shine on the floor outside the hutch. (Photon source is scattered photons in 90 ° direction by Cu at 2m from scattered point. W denotes width)

The ground shine which is caused by the scattering photons from the concrete ground were also considered. For the purpose, another type of hutch wall composed of lead plate of 10mm thick sandwiched by iron plates of 5 mm thick was employed. The calculation was performed with ITS3.0(6) and G33-GP(7), assuming synchrotron radiation perpendicularly scattered by Cu scatterer. As shown in Fig.2, the calculational result shows that the lead band of 30 cm or more in width and 2 mm thick is required along the foot of the hutch for attaining the dose which is equal to that at 1 m high from the floor.

4. GAMMA STOP

Gas bremsstrahlung is generated by the interaction of the stored electrons or positrons with residual gas molecules or ions in the storage ring vacuum chamber, which becomes important especially in the straight section because of an invasion into the beamline. Gamma stop made of lead is a standard beamline component of the SPring-8 to prevent bremsstrahlung from expanding to the down stream of the beamline.

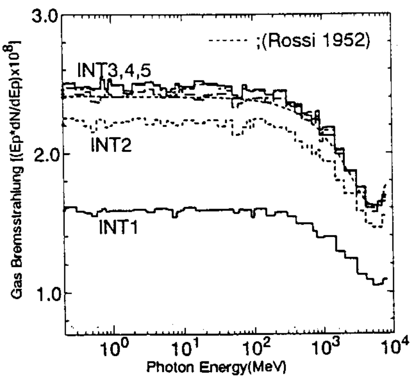

Fig.3 Gas bremsstrahlung spectra depending on the number of the interactions generated by EGS4 resulting from 0.1A 8GeV electron and interacting with 0.1205g/cm^2 air. (INT1;single interactions, INT2;double interactions, INT3.4.5; triple or more interactions, ---;theoretical data(8)(9))

The residual gas pressure is designed to be below 0.133 μPa(10^{-9} torr). The EGS4(10) calculated gas bremsstrahlung spectra are shown in Fig.3. As shown in the figure, the gas bremsstrahlung generated within single interactions between the electrons and 0.1205 g/cm^2 air molecules is about 60% of that generated within multi-interactions. The bremsstrahlung is nearly saturated within triple or more interactions. In case of the interactions with 0.01205 g/cm^2 air molecules, the gas bremsstrahlung generated within single interactions is almost saturated. Most of the bremsstrahlung is emitted within 0.1 mradian.

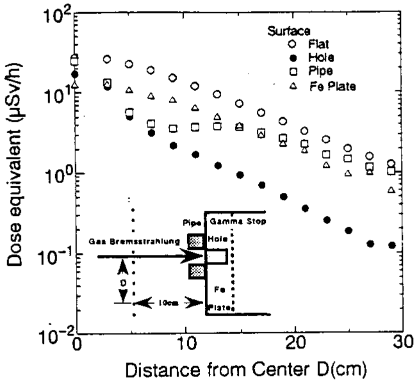

Fig. 4 Dose distribution due to back scattering by the gamma stops of various shapes. (Doses are at the point D(cm) from the center of the beam on the plane set at 10 cm in distance. Hole size;1cm in radius and 3cm in depth, Pipe size; 4cm in outer radius,3cm in thickness and 3cm in length, Iron plate; 5cm in thickness).

On the basis of the results of the EGS4 calculations, together with tabulated data(3), the gamma stop of 30 cm in thickness and 26 cm in diameter is recommended. Dose distribution due to the back scattering that depends on the shape of the gamma stop was calculated. As shown in Fig.4, the gamma stop with a hole is found to be beneficial to reduce the dose due to the back scattering.

The photoneutrons are produced through the interactions of gas brems-