# Calculation of Gas Bremsstrahlung and Associated Photoneutron at SPring-8 Insertion Device Beamline

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## 1. Introduction

A generation of photoneutrons in a beamline is one of the serious problems of safety on synchrotron radiation beamlines, which requires an additional shielding. The photoneutrons are produced through interactions between beamline components and gas bremsstrahlung generated in an accelerator storage ring. At HASYLAB of DESY, the shielding against the photoneutrons has actually been a significant item of radiation protection on beamlines. In the third generation facilities, such as ESRF, APS and SPring-8, the intensities of gas bremsstrahlung and photoneutrons are seriously high because of the introduction of insertion devices onto very long straight sections in a high- energy and high-current storage ring. Therefore the photoneutron production process is significant in the shielding calculation for the beamline.

## 2. Gas bremsstrahlung

The gas bremsstrahlung is generated by an interaction of the stored electron or positron with residual gas molecules or ions in a storage-ring vacuums-chamber. It becomes important especially in the straight section because of its invasion into the beamline.

The residual gas pressure is needed in real operation to be below 0.133 μPa ($10^{-9}$ torr) and the calculated gas bremsstrahlung is shown in Fig.1 by using EGS4[1]. As seen in Fig.1, the gas-bremsstrahlung generated through single interaction between the electrons and 0.1205 g/cm$^2$ air molecules is about 60% of the total. The gas bremsstrahlung is nearly saturated within triple interaction or more. In case of the interaction with 0.01205 g/cm$^2$, the gas bremsstrahlung generated through single interaction is nearly equal to a saturated one. In order to avoid an over-estimation to be occurred in scaling from 0.1205g/cm$^2$ air molecules to $3.01\times10^{-14}$g/cm$^2$, the result of gas bremsstrahlung through single interaction was used.

## 3. Photoneutron production yield

The track-length distribution of gas bremsstrahlung within the lead gamma stop (20 cm in radius and 30 cm in length) were calculated on the standard insertion device beamline by using the Monte Carlo code EGS4.

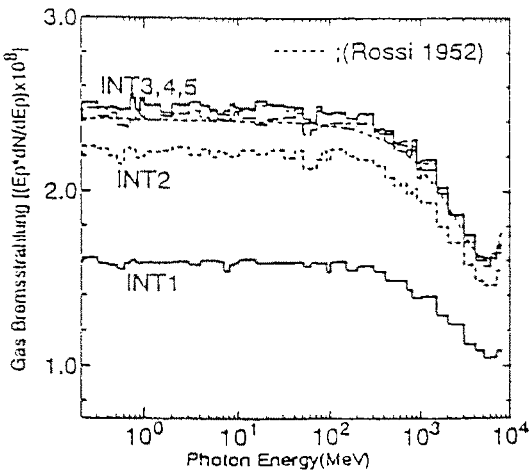


Fig.1 Gas bremsstrahlung spectra depending on the number of the interactions (generated by EGS4) resulting from 0.1A 8GeV electrons interacting with residual air-gas in the SPring-8 normal straight section. The EGS4 calculations were performed with 0.1205g/cm$^2$ air and in scaling to $3.01\times10^{-14}$g/cm$^2$ air (INT1;single interaction, INT2;double interactions, INT3.4.5; triple interactions or more, ---;theoretical curve[2],[3] ).

The neutron yield, $N(En)$, is given by,

$$N(En) = \int dL(E\gamma)/dE\gamma \cdot \sigma(E\gamma, xEn) \cdot dE\gamma \quad (1)$$

where $dL(E\gamma)/dE\gamma$ is the photon track-length distribution and $E\gamma$ the photon energy. $\sigma(E\gamma, xEn)$ is the photoneutron production cross-section which produces the $x$ number of neutrons with $En$ energy. The cross-sections obtained from Dietrich and Berman[4] were used in the calculation. Figure 2 shows the neutron yield distribution within the gamma stop. In the figure, neutron production from the quasi-deuteron and photopion reactions which can be induced by photons higher than about 40 MeV was ignored.

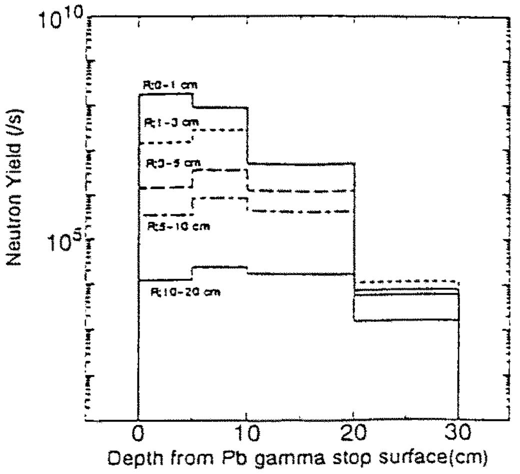


Fig.2 Neutron production distribution due to gas bremsstrahlung in lead gamma-stop (R:radius).

The energy spectra of the total neutron yield were obtained by using the Lorentz fitting from the Dietrich and Berman's data for neutron production and the maxwellian[5] for the neutron emission energy. The results are shown in Fig.3 together with the data by using other photoneutron production cross-sections generated with MCPHOTO[6] and PICA[7] up to 400MeV photon energy.

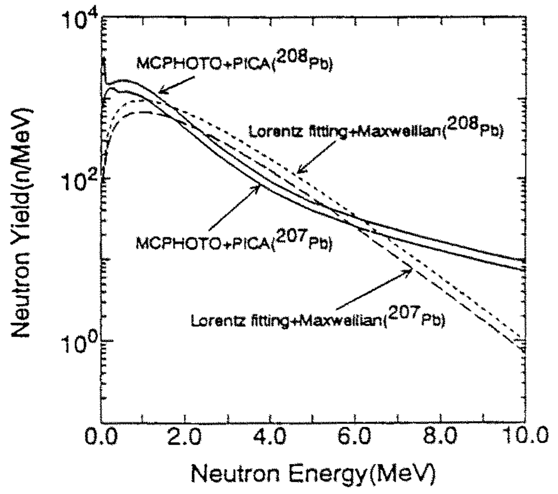


Fig.3 Calculated results of photoneutron production spectra by using track-length distribution and photoneutron production cross-section (Lorentz fitting + Maxwellian and MCPHOTO +PICA)

## 4. Dose of photoneutron

On the assumption that the target is a point source and the neutron emission is isotropic, the effective dose equivalent rates at 1 m from the center of the gamma stop are 1.72 μSv/h, 1.24 μSv/h 1.95μ Sv/h and 1.45 μSv/h for $^{208}$Pb(Lorentz fitting + Maxwellian), $^{207}$Pb(Lorentz fitting + Maxwellian), $^{208}$Pb( MCPHOTO + PICA code) and $^{207}$Pb( MCPHOTO + PICA code), respectively.


**References**

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