AIR ACTIVATION BY AN ELECTRON SYNCHROTRON

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Abstract

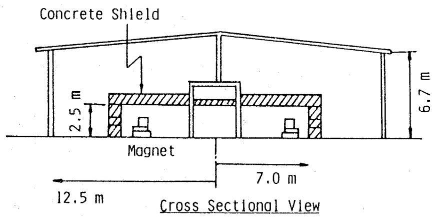
The air activation of ^{13}N, ^{15}O and ^{41}Ar in air of the room housing the 1.3 GeV INS (Institute for Nuclear Study) electron synchrotron (ES) was estimated by an experiment and a calculation.

It is of fundamental interest and importance for radiation protection to estimate accurately the generation of gamma rays and neutrons from a high energy electron accelerator. Here, we take up INS electron synchrotron (see Fig.1.), which was operated at 725 MeV and 176 W beam power. Some of the 725 MeV electrons are converted to high energy photons for an elementary particle experiment by colliding with a platinum internal target and the residual beams (more than 99%) are decelerated in the ring and enter the iron yoke magnet. The 725 MeV electrons lose their energy accompanying the electromagnetic cascade shower in the magnet and produce many photons by the Bremsstrahlung. These photons produces ^{13}N and ^{15}O ($T_{1/2}$=10.0 m and 2.07 m) by (γ,n) reaction with air. A part of photons also produces neutrons by (γ,n) reaction of magnet iron and the produced photoneutrons are slowed down in the synchrotron room. The thermalized neutrons activate ^{40}Ar (1.286 o/w of air) to ^{41}Ar ($T_{1/2}$=1.83 hr) by (n,γ) reaction.

The experiment was done under the condition that the ES operation was long enough for the steady-state concentrations of ^{13}N and ^{15}O to be reached. The induced activity of ^{13}N and ^{15}O in the room was measured with an NaI(Tl) scintillator to be 119.7 μCi and 47.0 μCi, respectively, immediately after the operation. To estimate the generation of ^{41}Ar, which has longer half life, the thermal neutron flux in the synchrotron room was measured by Au-activation foil. The average neutron flux in the synchrotron room was $(1.06 \pm 0.53) \times 10^4$ $n_{th}/cm^2/s$.

For the analysis of photons and the produced ^{13}N and ^{15}O, a model calculation was done and the experimental value was evaluated within 20 % underestimation. In this calculation the emitted photon flux were calculated by the Monte Carlo code, EGS, for the electromagnetic cascade showers, and these photon energy spectra were multiplied by the (γ,n) photoneutron reaction cross sections to calculate the the production of ^{13}N and ^{15}O. From this analysis, it becomes clear that the usual method of estimating the photons at an electron accelerator by using the forward Bremsstrahlung spectrum of a thin target, is quite inaccurate when electrons are incident on a bulk structure or impinge on a magnet at a small angle of incidence. In such a case, one must consider that the photons are emitted mainly by backscattering, and have a considerably softer spectrum than the thin target Bremsstrahlung.

For the analysis of neutrons, the generation of photoneutrons and the slowing down and the thermalization process caused by high energy electrons have been analyzed by the combination of an electromagnetic cascade shower calculation and a two-dimensional S_N neutron transport calculation. The calculated thermal neutron flux is 2.11 x 10^4 $n_{th}/cm^2/s$ and the comparison between experiment and calculation was fairly good within factor two. This thermal neutron flux is applied to the estimation of radioactive ^{41}Ar generation of the electron synchrotron room and the obtained radioactivity of ^{41}Ar was 25.5 μCi.



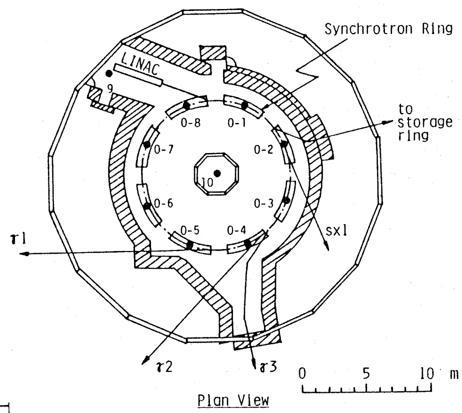


Fig.1. Layout of the electron synchrotron.

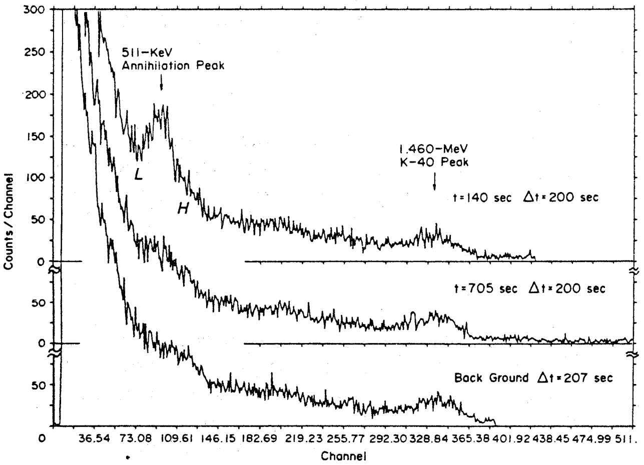


Fig.2. Pulse-height distribution of γ-rays from activated air, measured by an NaI(Tl) detector. Symbols L and H indicate energy acceptance interval for 511 keV peak measurements.

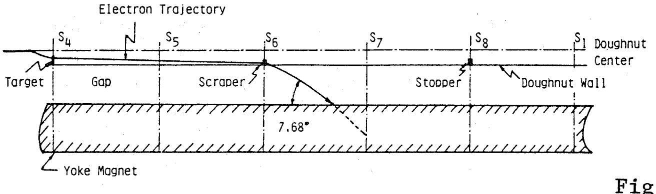


Fig.3. Electron beam trajectry on a horisontal electron orbit plane in the electron synchrotron ring.

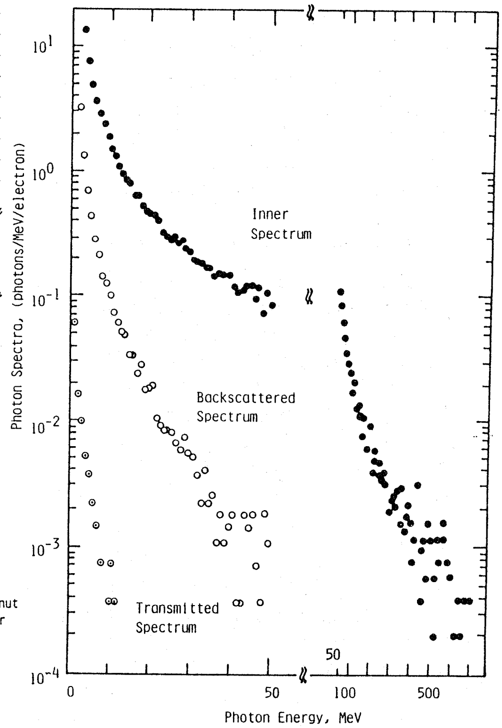


Fig.4. Photon energy spectra of 18 cm thick iron slab injected by a 725 MeV electron at an incident angle of 7.68 deg, calculated by EGS code.