DESIGN STUDY OF LOCAL SHIELDING ROOM FOR KOBRA FACILITY

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The design study of the local shielding room for RI beam separator KoBRA (Korea Broad acceptance Recoil spectrometer and Apparatus) is presented. We determined the design of the local shielding room satisfying our criteria (less than 150 neutrons/cm^2/sec at F3 focal plane and 1 Sv/h at F1) to protect experimental devices, using the Monte Carlo simulation codes, MCNPX and PHITS. The calculated neutron flux at F3 focal plane was calculated to be 130 neutrons/cm^2/sec with a conservative source term. Neutron dose rate at F1 was minimized to be less than 0.4 Sv/h using 0.8 m-thick conventional concrete wall with an additional iron shielding block. The activation calculation and residual γ-ray dose evaluation were also carried out for radiation safety assessment of the facility.

I. KOBRA FACILITY

KoBRA (KOrea Broad acceptance Recoil spectrometer and Apparatus) is a multi-purpose rare isotopes (RI) beam separator in low energy nuclear physics, which is being designed at Rare Isotope Science Project (RISP) of the Institute for Basic Science (IBS) in Korea. The stable beam from ECR ion source or RI beam from ISOL system is delivered to the KoBRA facility after acceleration by a superconducting linear accelerator up to about 20 − 40 MeV/nucleon. The maximum beam current is about 10 pμA. Details of the facility is described in Ref [1]. The main primary beam species in KoBRA are shown in Table I.

TABLE I. Primary ion beams for KoBRA facility

Ion	Energy (MeV/nucleon)	Beam power (kW)
^{4}He	40	1.6
^{11}B	40	4.4
^{18}O	40	7.2
^{40}Ar	40	16
^{238}U	18	43

II. DESIGN PROCESS OF THE SHIELDING ROOM

During operation of KoBRA, the incident primary beam pass through a production target with an energy loss of about 20%, and is stopped at a copper block (beam dump), thereby emitting large amount of secondary particles at both target and beam dump. The secondary particles, in particular neutrons, cause the radiation damages on the experimental devices such as electromagnets and detectors located along the beamline. The target and beam dumps are located at F0 and around exit of first bending magnet, respectively. Since the beam dump is placed at the limited space between bending magnet and F1 focal plane, a local shielded room which can cover the beamline around F1 was needed to protect the radiosensitive devices at F3 and F5 against the secondary particles. The design process in the study is summarized as followings: (1) source term calculation, (2) bulk shielding calculation, (3) selection of primary beam source, (4) design of geometry, (5) radiation transport simulation and (6) iteration until result satisfies requirement. To determine a source term conservatively, calculation results from both MCNPX [2] and PHITS [3] codes were compared. Neutron transport simulations for the changing geometry were performed by using MCNPX. Neutron flux of less than 150 neutrons/cm^2/sec at F3 and neutron dose rate of about less than 1 Sv/h were set to be the main criteria in this study.

Secondary neutrons also activate all surrounding objects such as iron frame of electromagnet, coil assembly, beam dump and concrete structures. Generated radioactive nuclides are accumulated during beam time and emit γ-rays due to the decay of excited nucleus. The activation calculation for the designed local shielding room was carried out using FISPACT-2010 [4], and the residual γ-ray dose rate was calculated with respect to the radiation cooling time.

III. RESULT

Fig. 1 shows the part of results about the estimation of secondary neutron flux and residual γ-ray dose rate. The neutron fluxes at F3 and F5 were calculated to be about 130 neutrons/cm^2/sec (4 μSv/h) and 190 neutrons/cm^2/sec (5 μSv/h), respectively. We found that most of γ-ray dose at F1 is caused by nearby concrete walls. After enough cooling time (about 6 days), the iron shielding block, located just downstream of the beam dump, becomes one of main γ-ray source, but the dose rate is below 5.7 μSv/h which is recommended dose limits of ICRP [5].

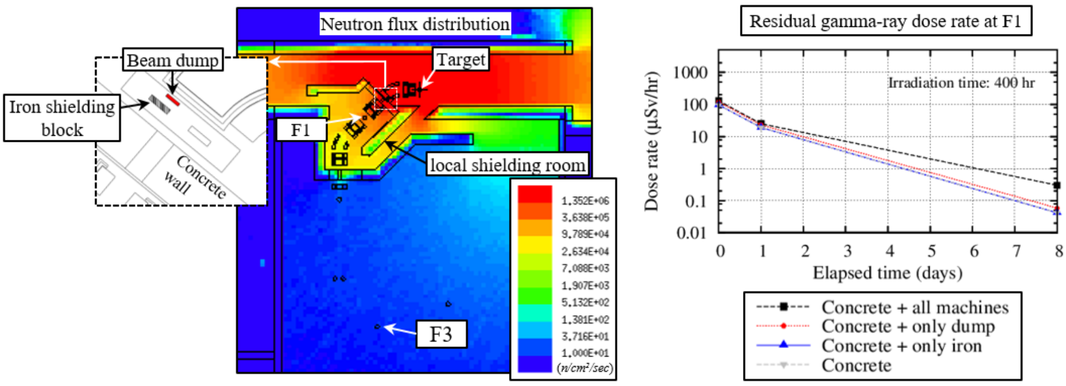

Fig.1. Calculated neutron flux (left) and residual γ-ray dose rate (right) at KoBRA. The ceiling of the shielding room is removed in the figure. The neutron intensity at the beam dump was calculated to be 4.63×10^{12} neutrons/sec using PHITS, for 32 MeV/nucleon ^{40}Ar primary beam of 10 pμA.

IV. CONCLUSIONS

The design study of local shielding room for KoBRA facility was performed using Monte Carlo simulations. The result of radiation transport simulation shows that the designed shielding room satisfies the required criteria. The activation calculation and residual γ-ray dose evaluation were also carried out and it is found that least 6 days cooling time is required after beam off, to access experiment devices.

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