JASMIN project
~ Japanese American Studies of Muon Interaction and Neutron detection~

None of the accelerators in the world can be operated without a radiation safety design that includes radiation shielding to maintain the exposure dose of radiation workers at the minimum possible value and estimation of induced radioactivity in air and water. In fact, all our accelerators have their own radiation safety design so that they meet the regulations specified by the Japanese government. Designing has been carried out using empirical equations based on the experience gained from other similar accelerators and theoretical calculation codes with physical models. In 2007, the JASMIN (Japanese American Studies of Muon Interaction and Neutron Detection) project was commenced to obtain basic data related to radiation safety design at energies greater than 100 GeV using a high energy accelerator at Fermilab, U.S.A. In this program, KEK physicists collaborate with other researchers and devise plans for experiments, data collection, analysis, and theoretical simulations. This program has produced various basic data to evaluate tools and techniques for radiation safety design.

For this program, the anti-proton production facility (pbar) and muon alcoves of the neutrino beamline (Neutrino from the main injector: NuMI) at Fermilab are selected because of simple shielding structure for precise simulations using a computer program, continuous operation for use in long-term experiments and intense beam operation for high sensitivity measurements. The 120 GeV protons utilized in both these facilities will provide data with the highest energy for these types of experiments.

A material placed in a radiation field becomes radioactive via nuclear reactions. The material emits photons whose energies depend on product nuclei. Therefore, energy measurement tells us what nuclei were produced. Several materials of disk- or foil-like shape were prepared (Fig. 1) and used at the pbar and NuMI facilities to obtain information on the induced activities. The experimental conditions were simulated using the multiparticle transport code. In Fig. 2, the data show activities observed from the experiments (dots) and calculation results (lines) at pbar. At NuMI, the activities induced in the samples by high energy muons were measured. Air in the pbar tunnel was also investigated for the production of ^{32}P, which could not be identified using conventional survey meters. By a combination of counting and radiochemistry, we successfully obtained the first set of data on the activities induced in various materials by secondary particles from the 120 GeV proton beam. The results prove that the codes can be used to simulate attenuation and reaction products of secondary particles from the 120 GeV proton induced reactions. The experiment will be continued to investigate the reason for the difference between these codes and the experimental data.

The energy spectrum and spatial distribution of the secondary particles at pbar and NuMI were also measured using neutron spectrometers and personal dosimeters. These data are useful for the design of a radiation monitoring system and dosimetry. The results were evaluated by computer simulation. Figure 3 shows an example of the results obtained for the radiation dose distribution at NuMI. The doses are measured by conventional dosimeters placed along a lateral tunnel in the rock positioned 800 m downstream of the target. The results show that the radiation dose around the high energy muon beam is equivalent to the sum of contributions from muons and other particles produced by the interaction between a muon and the rock.

All the data obtained in this program can be used to validate the results obtained with the theoretical calculation codes developed by combining the data of various elemental processes. Sometimes, the description and modeling of the elemental processes are revised and combined to accurately reproduce the experimental results. The results of this program are being shared to improve the radiation safety design and management of current and upcoming accelerators such as J-PARC, SuperKEKB, cERL, and ILC to support basic sciences using accelerators.

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Fig. 1. Preparation of test activation samples at pbar facility.

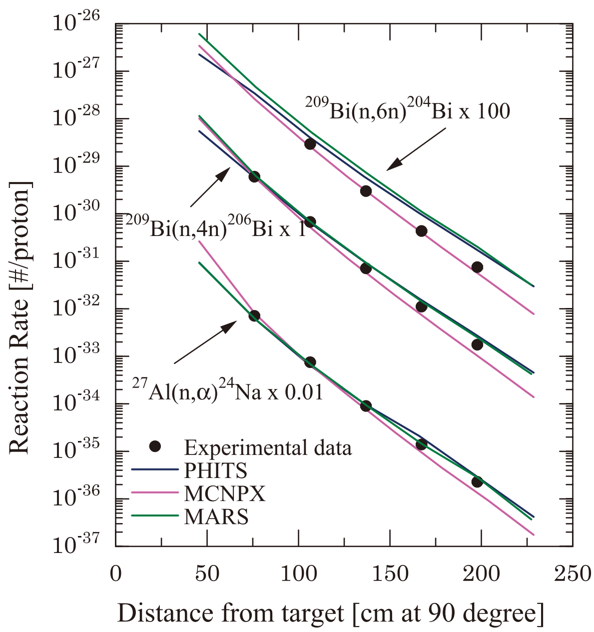

Fig. 2. Induced activities inside iron shield at pbar facility compared to the results of three different theoretical calculation codes, PHITS, MCNPX, and MARS. The three reactions have different reaction thresholds.

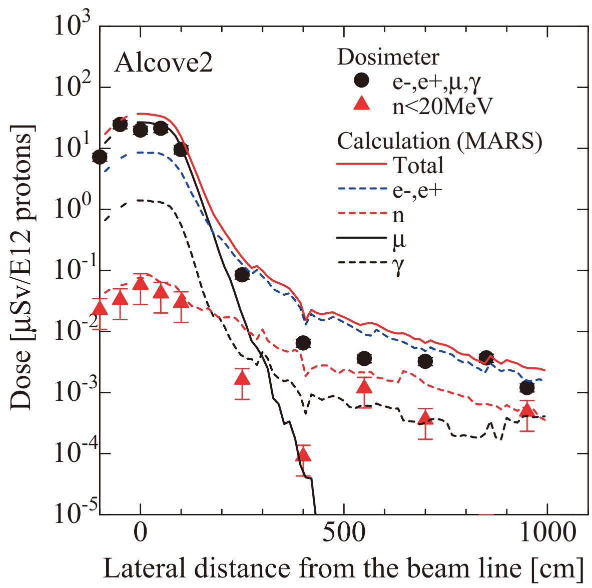

Fig. 3. The comparison between dosimeter measurements and simulation results for dose in alcove 2, located 800 m downstream of the target, behind a 12-m-thick rock.