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Measurement of high energy neutrons penetrating shields from GeV protons on a thick copper target

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Secondary neutrons are a significant concern in high-energy and high-intensity hadron accelerator facilities (e.g., J-PARC, CERN, SNS, ESS). The neutrons with energies from thermal to maximum energy contribute to external doses behind the shields and activate materials around the beamlines. For neutrons below 20 MeV, several techniques to measure their energy spectra and its reference field has been established. For neutrons above 20 MeV, only a few techniques and fields are available [1]. Thus, Monte Carlo codes (e.g., PHITS, FLUKA, MCNP) employing nuclear physics models and cross-section data are mainly used to obtain the energy spectra through particle production and transport. However, discrepancies among calculated results have been observed across different codes, particularly as the primary beam energy above GeV. Therefore, technique to measure neutron energy spectra above 20 MeV at facilities with incident energy exceeding 1 GeV is desired to obtain experimental data that enable us to validate the calculated results.

To obtain neutron spectrum above 20 MeV, a few detection techniques can be used behind the shields, including NE213 liquid scintillator, Bonner spheres, and activation foils. Recently, shielding experiments have been conducted employing these techniques for neutrons generated by 24 GeV/c protons and 50 cm long copper target at the CERN High-energy Accelerator Mixed-field (CHARM) facility in the East Hall of the CERN Proton Synchrotron (PS) [1-7]. Using an unfolding method with data obtained from NE213 scintillator, neutron energy spectra were derived. The spectra indicated high-energy neutron components (>100 MeV) [1]. The NE213 scintillator, however, has limited sensitivity to neutrons above 100 MeV, and thus, the shape of the neutron response matrix is less dependent on its energy, which may lead to uncertainty in the unfolding process.

To address this limitation, alternative detection methods are being studied. CsI(Tl) scintillator, known for its pulse shape discrimination (PSD) capability and high light yield, is one of the candidates for extending the measurable neutron energy range beyond 100 MeV [8-10]. However, several challenges, such as determining detector response characterization, energy calibration, and background suppression, must be overcome before actual application in the high-energy neutron field vicinity of high energy accelerator. Thus, this study aims to investigate the feasibility of using CsI(Tl) scintillators. In this presentation, we will introduce (1) the results of neutron energy spectra measurement using the NE213 scintillator at CHRAM facility and (2) the test results obtained with the CsI(Tl) scintillators under the same condition as that of the NE213 scintillator. For (2), we acquired waveforms for PSD to distinguish neutron events from gamma-rays and obtained cosmic-ray muon events for energy calibration. We will discuss how these measurements improve neutron detection above 100 MeV.

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