Characterization of Liquid Scintillator-based Compact Neutron Emission Spectrometers for D-D Neutron Emission Spectroscopy in the Large Helical Device

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D-D neutron emission spectroscopy in the neutral beam (NB) heated plasma provides a deeper understanding of slowing-down of injected energetic beam deuterons through measurement of Doppler broadening of beam-driven D-D neutrons. Works can contribute the systematic understanding of fast-ion confinement in stellarator/helical systems and excitation mechanism of magnetohydrodynamic (MHD) instability by fast-ions. In the Large Helical Device (LHD), D-D neutron emission spectroscopy is well advanced by three compact neutron emission spectrometers (CNESs) based on conventional liquid scintillator (EJ-301). A tangential sightline CNES was installed at LHD 6-T port to observe a significant Doppler shift of the neutron energy due to the high-energy tangential negative-ion-source-based perpendicular NB injections (N-NB) [1]. Two perpendicular sightline CNESs were installed at LHD 1.5-L port to observe a helically-trapped beam ion, created by the perpendicular positive-ion-source-based perpendicular NB (P-NB) and/or ion cyclotron range of frequency wave heating [2].

This work focuses on the characterization of three liquid scintillator-based CNESs at the neutron source facility and in the LHD experiments. Prior the installation of CNESs in the LHD, three 1-inch in diameter and 1-inch in length liquid scintillator coupled with a conventional 1-inch photomultiplier tube are characterized at fast neutron source facility, i.e., Fast Neutron Laboratory (FNL) of Tohoku University. The EJ-301 scintillation detector was placed at different position from the beam axis, where the D–D neutron energy peak at the detector position was expected to be up to ~6 MeV. The charge comparison method is used for neutron/γ-ray pulse shape discrimination. The simple derivative unfolding technique is used to unfold the neutron energy spectra from the recoiled proton energy spectra. To further understanding of detector response to the fast-neutrons, the deuteron beam's energy spectra in the D_2 gas target and the neutron transport in the FNL experiment hall was calculated by TRIM code and Monte Carlo N-Particle transport (MCNP) code. In the LHD experiments, the operational capability of the CNESs in the pulse counting rate is investigated. D-D neutron emission spectroscopy in various approaches during the N-NB and P-NB heated plasma using liquid scintillator-based CNESs in the LHD are characterized and compared with the numerical simulation based on the orbit following model.

[1] S. Sangaroon et al., AAPPS Bulletin **32**, 5, 2022.
[2] S. Sangaroon et al., Review of Scientific Instruments **93**, 093504, 2022.