Design Study of Hard X-ray Spectrometer Array for Suprathermal Electron Measurement in Compact Helical Device

Yinghan Wu [1], Kunihiro Ogawa[1,2], Longyong Liao[2], Worathat Paenthong[1], Sheng Dong [1], Siriyaporn Sangaroon[3], and Mitsutaka Isobe[1,2,3]

[1]*The Graduate University for Advanced Studies, SOKENDAI, Toki, Gifu, Japan*
[2]*National Institute for Fusion Science, National Institutes of Natural Sciences, Toki, Gifu, Japan*
[3]*Mahasarakham University, Maha Sarakham, Thailand*
Corresponding Author Email: wu.yinghan@nifs.ac.jp

Compact Helical Device (CHD), which is the upgrade of Compact Helical System (CHS), is scheduled to be operated from late 2026. Research on the excitation mechanism of magnetohydrodynamic (MHD) instability and its effect on plasma confinement is the one of the research targets. In CHS, excitation of MHD instability due to the suprathermal electron was observed. However, the excitation mechanism as well as suprathermal electron energy and spatial distribution were not fully understood yet [1]. To understand the energy and spatial distribution of suprathermal electrons in CHD plasmas, we are now designing hard X-ray spectrometer array.

The hard X-ray spectrometer consists of multichannel collimator, 16 scintillation detectors, and a fast data acquisition system. We designed 300 mm (width) × 300 mm (depth) × 800 mm (height) multichannel collimator with 16 holes made of ~800 kg lead based on the three-dimensional radiation transport calculations. For hard X-ray scintillation detector, we chose a leading-edge $LaBr_{2.85}Cl_{0.15}$:Ce (LBC) scintillation detector characterized by its high weight density, high brightness, high energy resolution, and fast decay time. Note that the fast decay time provides high time resolution measurement required for fusion plasma experiments. We compared energy resolution and decay time with commonly used scintillators, including NaI:Tl, CsI:Tl, $LaBr_3$:Ce, $CeBr_3$, and high-resolution $Gd_3(Ga,Al)_5O_{12}$:Ce (HRGAGG) using calibration gamma-ray sources. Compared with traditional scintillators such as NaI:Tl, CsI:Tl, the LBC scintillator has superior energy resolution and faster decay time. For the data acquisition system, we developed 12 bits with 2.5 GHz sampling rate data acquisition system which outputs the timestamp, waveform, and charge integral of each pulse. We will present the detail of hard X-ray spectrometer array for suprathermal electron measurement in CHD.

[1] M. Isobe et al., “Energetic-particle modes driven by suprathermal electrons produced by off-axis second harmonic ECRH in compact helical system (CHS)”, *Nuclear Fusion* **50**, 084007 (2010).