§4. Study on Measurement of Total Neutron Yield during Deuterium Experiments and its Calibration

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It is very important to measure the number of neutrons generated during deuterium burning experiments from a viewpoint of both scientific interests and radiation safety managements. There have been few experiences to measure the neutron yield and to calibrate neutron detectors for a complicated fusion experimental device such as the LHD. It is therefore important to study the calibration process for the LHD experiments.

We have modeled the LHD as a simple structure to calculate the neutron transport in and out of the LHD using the MCNP-4C2 code for these three years. We can now calculate the fluence rate and the energy spectrum of neutrons near the LHD. We can also calculate the response function of the candidate neutron detector for the DD neutrons and those from a ^{252}Cf source. In this year we studied the calibration process and the uncertainties associated with measurements of the total neutron yield. We also evaluated the influence of the liquid helium for cooling the superconducting coils that would not exist during the calibration process.

Table 1 shows the detection efficiencies of the candidate neutron detectors at different positions for neutrons from a ^{252}Cf source with and without the liquid helium. The no.1 and no.2 detectors are placed in front of the two different horizontal ports. The no.3 detector was set on the central axis and at height of 500 cm from the equatorial plane of the LHD. The shape of the ^{252}Cf neutron source was a ring with a radius that is the same to the major radius of the LHD, which emitted 2.5 MeV neutrons isotropically. The difference of the detection efficiencies obtained with and without the liquid helium was less than 3 %.

Table 2 shows the uncertainties associated with the neutron yield measurement, and the budget sheet of the uncertainties. The overall uncertainties for total neutron yield measurement were about 10 %, although they were slightly depend on the position of the detectors.

The subjects that is to be evaluated were the influences of the neutron energy, the direction of neutron emitted, and the position of neutron generation during NBI heating.

Publication: N. Nishio, A. Yamazaki, K. Watanabe, A. Uritani, M. Isobe and H. Yamanishi, "Study on the Calibration of LHD Neutron Monitoring System," Plasma and Fusion Research, **6** (2011) 2045115-1 - 2045115-4.

Table 1 Neutron detection efficiency at different positions

Detector position	Detector number	Detection efficiency [count/n]		Ratio of the detection efficiency
		without He	with He	
Outside of LHD device	#1	7.46×10^{-8}	7.28×10^{-8}	0.98
	#2	7.76×10^{-8}	7.77×10^{-8}	1.00
On the center axis	#3	5.25×10^{-8}	5.07×10^{-8}	0.97

Table 2 Budget sheet of uncertainties of neutron yield measurement

Detector number	Overall uncertainty of neutron measurement	Origin of uncertainty				
		Uncertainty of the Calibration factor α_{DD}	Non-linearity of Cambelling mode	Linearity of the mutual calibration	Variation of position of neutron production	Shift of Plasma
#1	9.6 %	3.4 %	1.0 %	5.0 %	5.5 %	5.0 %
#2	9.7 %	3.5 %				
#3	10 %	4.2 %				