Neutron monitoring and in-situ detector calibration at the Wendelstein 7-X stellarator

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The neutron monitor system of the W7-X stellarator consists of three sets with up to five neutron detector tubes of different sensitivities to thermal neutrons in a dedicated moderator geometry in order to realize a nearly constant response independent of the neutron energy. The monitors have been designed to cover the expected neutron yields in deuterium plasmas from 10^{11} up to 10^{16} neutrons per second with a time resolution of 5 ms and a statistical uncertainty of better than 15 %. This corresponds to neutron fluence rates from 10^3 cm^{-2} s^{-1} to 10^9 cm^{-2} s^{-1} at the location of the monitors. The central monitor is located 3.9 m above the equatorial mid-plane of W7-X, the two peripheral monitors are placed outside the cryostat at a distance of 0.8 m from the vessel at a height of 1.6 m above the equatorial plane directed towards the plasma axis. The monitors have been characterized in the neutron reference fields of the Physikalisch-Technische Bundesanstalt (PTB) to validate the specified properties.

The objectives of the neutron monitors of W7-X combine the documentation of the total neutron emission per year and the monitoring of the maximum neutron emission rate as well as the determination of the neutron flux rates measured at different positions around the W7-X verifying physical plasma parameters such as the ion temperature and deuterium density.

In order to determine the neutron emission produced by D(d,n)^{3}He fusion reactions in the plasma an in-situ calibration with a neutron source of known source strength is required. The results of such a calibration procedure depend on the entire scattering behavior of the neutrons by all W7-X materials and its environment, starting inside the plasma up to the detector tubes inside the neutron monitors. This is why we have performed two in-situ calibrations, one before the first operation of W7-X in a limiter configuration without graphite tiles in January of 2015 and one after the installation of the divertor targets including uncooled graphite tiles in March of 2017. The procedures of these in-situ calibrations will be described and the results compared to predictions of Monte-Carlo calculations (using the MCNP code) of the neutron propagation from the location of the neutron source to the neutron monitors using a simplified model of W7-X.