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Diagnosing transient fusion plasmas with neutrons – recent progress in time-of-flight and thin-foil proton recoil techniques

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Neutron spectroscopy has proven to be a versatile method for probing the state of plasmas (fuel) used in fusion energy research. Therefore, it is likely that the next generation fusion experimental reactors, like ITER, will be equipped with a suit of neutron spectrometers. Parameters like fuel ion temperature, fuel ion non-thermal energy distribution, fuel ion density, fusion power, etc. can be extracted from data provided by such instruments. However, the application of neutron spectroscopy to fusion plasmas put special demands on the instruments. Since fusion plasma conditions can vary rapidly, one of the most important requirements is high count rate capability to provide data of high statistical significance over short time periods and thereby good time resolution in the extracted plasma parameters. This requirement can be met in different ways depending on plasma conditions and the diagnostic technique employed. In addition, the harsh radiation and demanding interfacing conditions on ITER can restrict the application of certain techniques. In this contribution we review recent progress in two of the most promising neutron spectroscopy techniques suitable for ITER, namely, the time-of-flight (ToF) and the thin-foil proton recoil (TPR) techniques.

In fusion time-of-flight neutron spectroscopy the highest signal rates to date have been achieved with the TOFOR spectrometer at JET. Signal rates of about 50 kHz over several seconds were achieved in high performance plasma operations in 2009, with a maximum signal rate capacity estimated to 500 kHz in 2.45 MeV neutron measurements. At such rates it has until recently been possible to record only the most crucial event information, i.e., the precise time of each eligible event; additional event information (e.g. pulse heights) has been sacrificed for the sake of acquisition speed. Developments in digital data acquisition technology has now made it possible to record correlated time and pulse shapes (energy) at rates approaching those required for use in high-rate ToF applications. We present results from tests on a set of data acquisition boards provided and customized by Signal Processing Devices. The boards digitize the detector pulses at rates up to 2 Giga-Samples per Second with 12 bit ADC resolution, as well as offering flexible triggering and time synchronization options –we show that such cards indeed are suitable for the intended ToF application.

As shown by the present MPR installation on JET, the thin-foil proton recoil technique can provide results of high quality in the most demanding fusion experimental conditions (high power DT plasma discharges). The non-magnetic TPR technique is an interesting option for a 14-MeV neutron spectrometer on ITER as it combines many of the positive traits of the MPR with a simplified interfacing, due to the absence of a magnetic spectrometer. We show results from simulations of TPR performance in terms of signal to background, and indicate a conceptual design of a TPR instrument for ITER.

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