Measuring fast ions in fusion plasmas with neutron diagnostics

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A high-performance fusion plasma inevitably contains a population of supra-thermal ions, with energies in the range from ~100 keV to a few MeV, that are produced either in the fusion reactions or by the plasma heating systems. Such “fast ions” can drive plasma instabilities, and their confinement in the plasma is important to maintain the high temperature required for fusion. Fusion plasmas consisting of deuterium (D) or a deuterium-tritium mixture (DT) are sources of intense neutron emission due to the D+D and D+T fusion reactions (at the JET tokamak neutron rates of $5.5{\cdot}10^{16}$ s^{-1} and $5.7{\cdot}10^{18}$ s^{-1} have been achieved in D and DT plasmas, respectively), and fast ions often leave characteristic signatures in the neutron emission. In this presentation, we will show how neutron measurements can be used to study fast ions and give examples of results obtained at JET and other present day tokamaks.

It is often possible to determine the fast D energy distribution from neutron spectroscopy measurements. With this technique it is possible to study energy dependent interactions between the fast ions and MHD activity, as well as the fast ion dynamics in plasmas heated with neutral beam injection (NBI) and ion cyclotron radio-frequency heating (ICRH).

An even more detailed picture of the fast ion distribution can be obtained by combining several different diagnostics. We show how the fast ion distribution can be resolved in both energy and pitch angle by combining neutron and gamma-ray measurements obtained along several different sightlines using velocity-space tomography.

Finally, we give an outlook about neutron-based fast ion measurements at the next generation fusion experiment, ITER.

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