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Neutronic Design of the ITER Radial Neutron Camera

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Two neutron camera systems (radial and vertical) are envisaged in ITER for a full scanning of the plasma. The radial neutron camera (RNC), which should provide information (with a 10% accuracy) on the spatial and energy distribution of the neutron emission, consists of an ex-vessel system with detectors in 12x3 lines of sights and a fan-like collimator 400 cm long and an in-vessel system which accommodates further 9 lines to extend the coverage of the plasma up to =0.87 (=r/a, a minor radius of the plasma). This paper summarizes the work, performed in the frame of various EFDA contracts during 2004-2005, on the design review and upgrade of the radial neutron camera.

A Monte Carlo code (MCNP, version 4C3 and 5) has been used for the neutronic calculations. The basic ITER model has been developed to include the RNC with all the details relevant for the neutronic analysis. CAD based drawings with position inquiring software have been used for a reliable modelling. Various collimator diameters have been considered: 1-2 cm and 2-4 cm, respectively, for the ex-vessel and in-vessel systems. A standard fusion neutron source with a constant 10 keV temperature has been assumed. A special variance reduction treatment has been developed to force neutrons to score in the far regions in the high collimated neutron beam, in order to obtain a low statistical error. DD and DT phases in various plasma scenarios have been studied by providing the MCNP code with a proper probability matrix from which the starting neutrons are sampled.

Neutron and photon (due to inelastic scattering and radiative capture of neutrons) fluxes and spectra have been calculated. Approximately, one neutron out of 1011 emitted in all the plasma can reach one of the ex-vessel detectors. Therefore, for an emission rate of 1.81020 n/s (corresponding to a 500 MW fusion power) the ex-vessel detectors can detect from 1108 to 6108 neutrons depending on the poloidal orientation. Similar values are obtained for the in-vessel detectors (having shorter collimator length and larger diameter and pointing to a lower emission plasma zone). The fraction of scattered neutrons (above 0.1 MeV) is in the range 0.1-0.4 % of the total.

A measurement simulation software tool (MSST) performing asymmetric Abel inversion of simulated measured neutron signals has also been developed for line of sight optimization. Combining information from MCNP calculations for the DD and DT phases and from MSST runs, it has been possible to evaluate the performance of the RNC and to check whether the present design of the RNC meets the measurement requirements. The layout of the lines of sight has been modified based on results from MSST.