3rd Workshop on Calibration of ITER Neutron Diagnostics

Wednesday 05 October 2022 - Friday 07 October 2022

ITER Site

Program

Motivations for the Workshop

A central theme of this workshop is on the quantification of the neutron measurement errors. Participants are invited to introduce and discuss solutions and recommendations for improving and optimizing the diagnostics, their calibrations and the numerical framework leading to highly accurate measurements.

Background

The neutron diagnostics are poised to provide ITER with key measurement parameters such as:
the Fusion Power and the Fusion Power Density;
the Neutron-and-Alpha-Source Profiles;
the Total Neutron Flux;
the First-Wall Neutron Fluence;
the D/T Density Ratio in the plasma core, etc.

The success of ITER will come through its ability to produce large amount of energetic neutrons, i.e. fusion power (500 MW). The neutron diagnostics are therefore essential for achieving ITER goals as well as for machine protection, plasma control and physic studies.

The Domestic Agencies (DAs) are responsible for the design and manufacturing of the neutron diagnostics:
Neutron Flux Monitors (NFM) in radial diagnostic ports [**CN DA**]
Divertor Neutron Flux Monitors (DNFM) under the divertor dome [**RF DA**]
Micro Fission Chambers (MFC) between the blanket modules and the inner shell of the vacuum vessel [**JA DA**]
Neutron Activation System (NAS) with irradiation ends at various locations inside the vacuum vessel [**KO DA**]
Radial Neutron Cameras (RNC) with multiple lines of sight from Equatorial Port #1 [**EU DA**]
Vertical Neutron Camera (VNC) with multiple lines of sight from Upper Port #18 and Lower Port #14 [**RF DA**]
High Resolution Neutron Spectrometer (HRNS) in Equatorial Port #1 [**IO/EU**].

Calibration and Characterization Plans for the Detectors and Diagnostic Assemblies prior to installation on ITER

It is very important that the neutron diagnostic subsystems are fully calibrated and characterized before delivery to ITER. The calibration requirements depends on the specific types of detectors and the diagnostic assemblies. The DAs and IO should agree on coherent pre-delivery calibration plans with particular attention to the range of neutron energies and the number of calibration points, the sensitivity to operating conditions (temperature, electromagnetic fields) and the impact of the diagnostic assembly.

In Session II, representatives of each DA are invited to present and discuss the accuracy of the diagnostics for which they have responsibility and to outline their plans for calibration and characterization procedures of these systems prior to delivery at ITER.

Detector & Diagnostic Assembly Models and Their Validations

Development and validation of neutronic models will be critical to ensure the ultimate accuracy of the measurement parameters on ITER. MCNP models of the detector assembly will be plugged into the whole tokamak model geometry for calculations of the in-vessel neutron calibrations and subsequently for interpretation and analysis of the experimental data. Validation of the models will involve using data from the calibrations of the individual detectors as well as from the sensitivity study of the assembly to temperature and electromagnetic perturbations.

In Session III, representatives from the DAs and independent experts are invited to present and discuss the development and accuracy of neutronic models for the detectors and diagnostic assemblies.

In-Vessel Neutron Calibration (IVNC) Planning

The in-vessel neutron calibration will have to be carried out when ITER is fully assembled and poised to start nuclear operation. In-vessel calibration of the neutron diagnostics could involve an extensive – and unacceptably long – period of in-vessel work. The object of the present session is to formulate an optimized in-vessel calibration plan aimed at characterizing the sensitivity of the diagnostics with respect to the location of a neutron source as well as the neutron transport within the vacuum vessel and the port areas.

During Session IV:
- The IO will outline recent progress in the planning of the IVNC campaigns;
- Representatives from the DAs and independent experts are invited to present and provide recommendations to the IO for the in-vessel calibrations of the most sensitive diagnostics;
- Participants are invited to advise IO on the optimization of the IVNC campaigns in order to minimize neutron measurement errors;
- Participants are invited to share the lessons they learned during IVNC campaigns at other facilities (JET, LHD, etc).

ITER Neutron Transport Calculations and Cross-Calibration Considerations

The data obtained during the in-vessel neutron calibration campaigns will be used to tune and validate the MCNP tokamak model geometry and the neutronic calculations. Also, while the IVNC will have to concentrate on calibrating a limited number of the most sensitive detectors, other neutron diagnostics will be cross-calibrated using standard reference plasma shots. The success of the cross-calibrations will depend strongly on the accuracy of the neutronic calculations and plasma models.

In Session V, representatives of the DAs and independent experts are invited to present and discuss the development and validation of detailed MCNP models for ITER as well as the accuracy of the cross-calibrated diagnostics.

Calibration, Simulation and Measurement Accuracy

The relationship between the detected signals and the measurements, such as the total neutron emission rate, is very complicated and will require the use of neutronic calculations and synthetic measurement simulations. All together, the measurement errors can be significant and are challenging to quantify.

During Session VI, representatives from the DAs and independent experts are invited to address the following topics:
- Quantification of neutron measurement errors from numerical and experimental sources;
- Development and findings from synthetic measurement simulations of the neutron diagnostics;
- Development, sensitivity and accuracy of the existing plasma models;
- Strategies aimed at reducing the measurement errors.