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A Strategy for Calibrating the Neutron Systems on ITER

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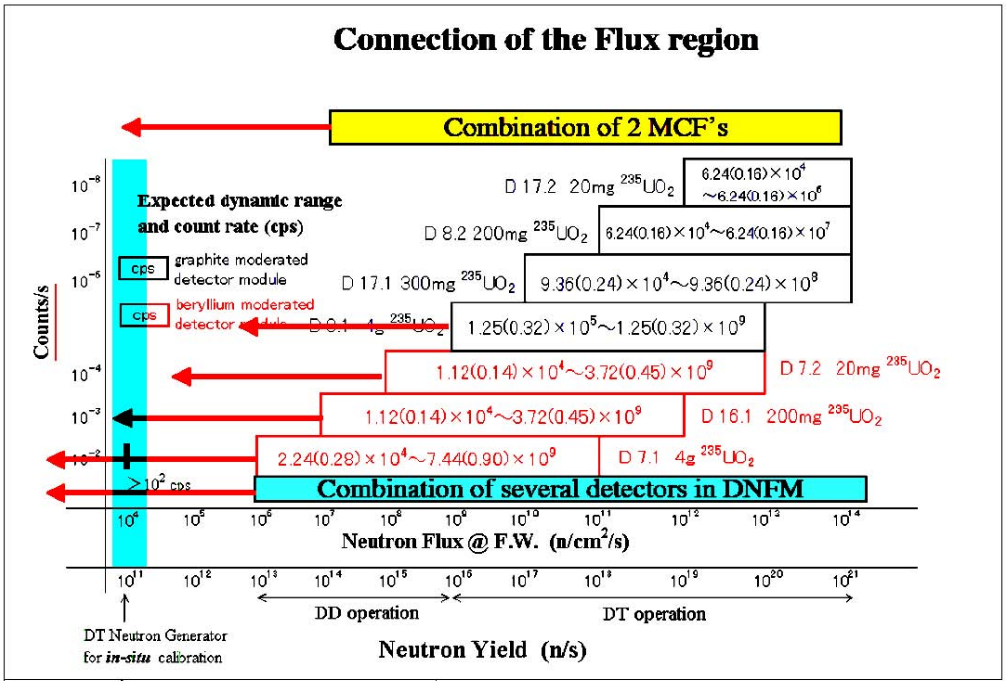
INTRODUCTION

Among the many plasma and first wall parameters to be measured at ITER, the neutron emissivity and the fusion power will play an important role for ITER plasma optimization and for achieving ITER goals [1], in particular the fusion gain factor Q related to the reactor performance. ITER requires quite challenging measurement requirements [2]: up to 1.5 GW within 10% accuracy, with a temporal resolution of 1 ms and spatial resolution of a/10. To meet these requirements several neutron diagnostic systems [3, 4] will be installed on ITER: Neutron Flux Monitors (NFM), Divertor Neutron Flux Monitors (DNFM) and MicroFission Chambers (MFC) located inside the vacuum vessel and in the diagnostics ports; neutron emission profile monitors/cameras and 2.5 and 14 MeV neutron spectrometers; foils encapsulated Neutron Activation System (NAS) with irradiation ends inside the vacuum vessel for neutron yield measurements. The ITER expected neutron emission strength spans over 7 decades (up to almost 10^{21} n/s) requiring detectors with different sensitivities (Fig.1).

On ITER the absolute calibration of the neutron diagnostic systems will be achieved by means of neutron/gamma *in situ* calibration campaigns and utilizing extensive calculations with neutron and gamma transport codes as already performed on large tokamaks (JET, TFTR and JT-60U) [3, 4]. Continuous activity [5] is carried out for reducing the uncertainties on:

i) neutron source strength measurements for the DD and DT phases (one single component neutron source); ii) neutron source strength measurements for the advanced DD phase which is a two components neutron source (due to the triton burn up) affecting the energy response of the detection systems; iii) *in situ* calibrations as consequence of the extended plasma neutron source, of neutron scattering due to the materials/structures surrounding the neutron diagnostics and of the various detectors response functions.



M. Sasao, 11th ITPA TG. Diagnostics,
Neutron Working Group, Sendai, Japan, Sept 2006

Fig.1. ITER neutron emission range and how it will be covered by the different proposed detectors.

ITER CALIBRATION STRATEGY

The planned *Calibration Strategy* at ITER (Fig.2) will be based on four phases: 1) full characterization and absolute calibration of all detectors carried out at the ITER Domestic Agencies sites; 2) detectors calibration at the Neutron Test Area on ITER site before installation on the Tokamak Complex; 3) *in situ* calibrations: DD and DT neutron generators and ^{252}Cf neutron passive sources will be moved inside the ITER Vacuum Vessel around different poloidal and toroidal positions to calibrate the Divertor Neutron Flux Monitors (DNFM), the Be-moderated Neutron Flux Monitors (NFM), the most sensitive detectors of the Radial and Vertical Neutron Cameras (RNC, VNC) and some irradiation samples of the Foils Neutron Activation system; 4) during the ITER DD and DT phases cross calibration campaigns will be performed to relate the other detectors by means of well characterized plasma reference shots.

Sufficient time will need to be dedicated to perform the ITER *in situ* calibrations. A preliminary scheme is under consideration of having a first short (~ 2 weeks) *in situ* calibration campaign either just before or in the first shutdown after the first plasma and then a complete in-situ calibration (8-10 weeks) before the DD-phase. With the first short calibration, based on few poloidal and toroidal irradiating positions, the aim is to cross check the experimental data with simulations obtained by means of neutron transport codes for determination and optimization of the *in situ* calibration time and of irradiating positions inside the Vacuum Vessel.

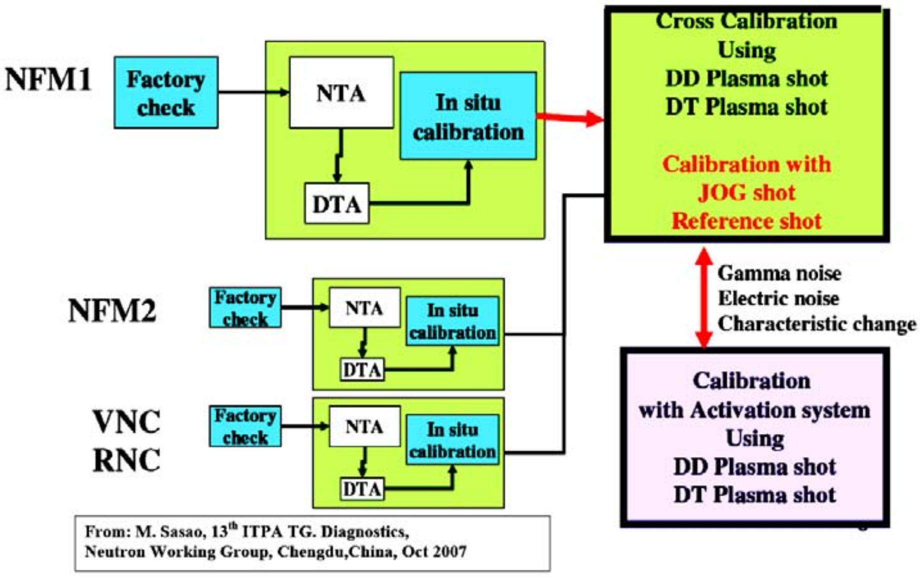


Fig. 2. ITER Calibration Strategy

ITER CALIBRATION REQUIREMENTS

Neutron generators (NG) and radio-isotope sources with extremely high emission rates are required for the calibrations. Dedicated R&D is necessary for ITER NG which should have the following features: strengths up to 10^{11} n/s at 2.5 MeV (NG –DD) and up 10^{12} n/s at 14 MeV (NG-DT), high accuracy of the emission properties, high level of stability during irradiation time, low scattering contribution due to NG structure and low neutron emission anisotropy, long operating life (several hundred of hours), compact-light structure and RH controlled. At present no commercially available NG satisfy all these requirements.

Performing high accuracy neutron measurements on ITER requires efforts on important calibration issues [5] such as: energy response of detectors to the different neutron energies, accurate determination plasma neutron emissivity profile, long term stability of the various detectors, methodology of frequent cross calibration campaigns with *ad hoc* plasma discharges to cross calibrate the various detectors with different sensitivities (linearity, different measuring techniques, errors evaluation).

In addition to an irradiation time providing an uncertainty of 1% in the counting statistics, the following accuracies requirements [5] have to be met for the *in situ* calibrations: neutron generator strength ≤5%, instability of the neutron generator ≤5%, ^{252}Cf source strength ≤2%, plasma center variation ≤2%, cross calibration (pulse to Campbell mode) ≤5%, calibration hardware scattering ≤5%, plasma neutron emission profile ≤ 5%, neutron source (NG) anisotropy ≤5%, stability of detector systems and electronics ≤2%.

CONCLUSIONS

A calibration strategy for high accuracy neutron measurements has been developed for ITER. It is expected that this strategy will provide a total uncertainty of 10% for ITER neutron strength measurements during DD and DT phases provided that the ITER neutron generators are available and that sufficient time for the *in situ* calibrations is available. Future work will be performed on: i) optimization of the calibration strategy aiming to a well characterized *in situ* and cross calibrations procedures; and ii) neutron generators and radio-isotope neutron sources.

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