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The ITER Research Plan and supporting R&D in present experiments

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The primary aim of the ITER Research Plan (IRP) is to define the plan of research and development and of the exploitation of the facility necessary to meet the ITER mission goals, which are:

• To achieve extended burn in inductively driven plasmas with the ratio of fusion power to auxiliary heating power, Q, of at least 10 ($Q \geq 10$) for a range of operating scenarios and with a duration sufficient to achieve stationary conditions on the timescales characteristic of plasma processes.

• Aim at demonstrating steady-state operation using non-inductive current drive with the ratio of fusion power to input power for current drive of at least 5.

The IRP is divided into two main phases, after first plasma demonstration, corresponding to operation in H/He plasmas (Pre-Fusion Plasma Operation (PFPO)) and with DD/DT plasmas (Fusion Plasma Operation). These two main phases are subdivided into experimental campaigns, separated by shutdowns, in which the tokamak ancillary systems (heating and current drive, fuelling, etc.) are progressively completed to their baseline configurations, which will be achieved before FPO following the Staged Approach [1].

The IRP describes the objectives of each of the operational campaign in consistency with the available tokamak systems and details the experimental plan to achieve them. It also identifies the main risks of the experimental plan to achieve the objectives of each phase and the corresponding mitigation actions, which include variations to the experimental plans in later phases of the IRP, upgrades to the ancillary systems, etc.

The main objectives of the two initial experimental campaigns (PFPO-1 and PFPO-2) is the achievement of high confinement plasmas (H-mode) and the demonstration of plasma operation up to the ITER design values for plasma current (15 MA) and toroidal field (5.3T) in L-mode plasmas. These experiments will characterize for the first time energy and particle confinement in a tokamak plasma at the reactor scale, to compare with the extrapolations made on the basis of present experiments that have been used for the ITER design and will determine the operational range for H-mode operation in H/He plasmas in ITER (this is expected to be limited to plasma currents/fields ~50% of the design values).

The demonstration of these high level PFPO goals will already require addressing the integration of many physics processes that are essential for the achievement of the high Q ITER goals such as: ELM control, disruption mitigation, control of power fluxes to plasma facing components, core plasma impurity control, etc., and the proposed experimental strategy to address them will be described.

The FPO campaigns cover a long operational period from the start of DD plasma operation, through the demonstration of the $Q = 10$ inductive goal, concluding with the demonstration of the $Q = 5$ long pulse goals. The experimental plan to proceed from DD towards high DT plasmas builds up on the results that are expected to be achieved in PFPO. It includes a verification of the L-mode development path demonstrated in PFPO and the initial expansion of the H-mode operational space in DD plasmas from low values of current and toroidal field gradually evolving towards DT plasmas with increasing T content plasmas culminating in the demonstration of the $Q = 10$ goal for a duration of 50s. The proposed experimental path allows the gradual assessment of physics and resolution of integration issues and tuning of plasma control schemes as the fusion power builds up with increasing T concentration and plasma current/toroidal field.

This initial phase is then followed by experimental campaigns focused on increasing the burn length of the inductive $Q = 10$ scenario towards the objective of 300-500s and the development of the long pulse $Q = 5$ scenarios where the optimization and control of the pressure and plasma current profiles will be a main focus of the research besides the scenario integration issues associated with high Q operation in ITER.

In order to ensure an efficient implementation of the IRP and to further optimize it, experimental R&D in present experiments, supported by appropriate modelling, is required. The presentation will describe the major issues that need to be addressed in order to refine the IRP and the proposed experimental/modelling strategies to refine the development paths considered in the IRP.

[1] Bigot, B., IAEA Fusion Energy Conference 2018.