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European Research Strategy for JT-60SA

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JT-60SA is a large fully superconducting new tokamak device being built under the Broader Approach Satellite Tokamak Programme jointly by Europe and Japan, and under the Japanese national programme. The JT-60SA tokamak will be at the forefront of the international fusion programme for many years, both before and during the D-T phase of the ITER operation. It will support the ITER experimental programme as a satellite machine and at the same time provide key information for the design of DEMO scenarios. The preparation of its scientific programme, described in the JT-60SA Research Plan, is progressing in the framework of a Japan-EU collaboration and will progressively integrate advances coming both from experiments on other tokamaks and theoretical developments.

In Europe, the preparation of the scientific exploitation of JT-60SA has been coordinated by EFDA (European Fusion Development Agreement) since 2011 through the JT-60SA EU Research Unit, in charge of both the Research Plan revision and the overall coordination of the collaboration activities concerning the JT-60SA physics. Starting from 2014, this task will be taken over by the EUROfusion Consortium through a Project called "Preparation of Exploitation of JT-60SA", which will prepare and implement a 5-year programme of R&D activities, covering the period 2014-2018.

The general goal of the European strategy can be summarised as follows: to prepare for a high level EU participation in the JT-60SA scientific exploitation, fully integrated in the EU fusion programme. This implies various objectives:

- diffuse the knowledge on JT-60SA characteristics, scientific goals, operation tools within the EU fusion physics community
- work at preparing the international part of the scientific programme for the JT-60SA campaigns
- prepare a full and efficient access to JT-60SA data and analysis tools for EU physicists
- prepare to play an active role in machine operation and campaigns management

The implementation of this programme is organised in three main areas:

1. Modelling. Integrated modelling of the JT-60SA reference scenarios is an essential step for the preparation of experiments. Furthermore, various specific physics aspects are being investigated and clarified in the areas of MHD, transport and confinement, fast particle physics.
2. Sub-systems. Specific studies are carried out in order to complete or improve the design of specific sub-systems of the machine, or to prepare their use. Examples of on-going investigations are: ECRH antenna, divertor pumping system, polarimetry diagnostic. Further studies on other diagnostics, pellet injection and metallic divertor are envisaged, following the main needs expressed by the Project Team.
3. Operation. These activities include the study of the main requirements of the JT-60SA data system, validation and analysis tools; the preparation of the methods and procedures of tokamak operation; the elaboration of the structures and methods of campaign management.

In these three areas, significant results have already been achieved and will be summarised in this presentation. Here some examples are briefly discussed.

Modelling. A coordinated Japan-EU modelling activity has started with the ambitious goal of providing predictive simulations of the main JT-60SA scenarios that could help in a detailed definition of the properties of various machine subsystems (H&CD, control coils, diagnostics) and at the same time could represent a reliable starting point for plasma operation. The first milestone of this activity is the critical comparison and benchmark of Japanese and EU models and codes used for integrated tokamak modelling, as well as H&CD. The second milestone is the validation of the main models and simulation framework used in both Japanese and EU integrated modelling suites of codes [1]. These include, e.g., energy and particle transport models, pedestal models, rotation sources and transport, synthetic diagnostics. It appears that simulations of JT-60SA scenarios should be based at least on experimental results of the two machines that are the most similar, for size and configuration: JT-60U and JET. On this basis, a validation exercise has been undertaken, involving: i) data exchange of reference JT-60U and JET shots, representing the main scenarios (H-mode, hybrid, advanced); ii) predictive simulations of the reference shots with both Japanese and EU codes and models (in particular, TOPICS and CRONOS), with the aim of finding a unified modelling framework that works for both machines: this should give the maximum confidence for prediction of JT-60SA scenarios. The third milestone is the predictive modelling of JT-60SA scenarios, logically to be carried out after the previous steps are completed. Preparation of this activity has been done by simpler models, both 0-D and 0.5-D (the METIS code) [2]. Simulations with 1.5 D codes of the flat-top phase of selected scenarios have also started [3]. Modelling of Resistive Wall Modes [4] and Neoclassical Tearing Modes [5] control has been undertaken.

Sub-systems. Various elements of the JT-60SA ECRH launcher have been analysed, in order to start an assessment of its performances. For each wave beam the antenna is composed of two mirrors. The first one is a flat mirror positioned in front of the tip of the 60.3 mm corrugated waveguide. This first mirror reflects the beam towards a wide, fixed cylindrical mirror. The size and the curvature of the cylindrical beam have been optimized in order to obtain the required poloidal and toroidal angular range.
First modelling of the JT-60SA divertor pumping system has been accomplished by means of the EU state-of-the-art code ITERVAC, including full divertor/pumping system geometry from CAD.
An extensive document on JT-60SA diagnostics has been written: "Technical review of diagnostics for JT-60SA". The document summarises the results of the analysis of the present design of the JT-60SA diagnostics system that had been carried out during the revision process of the Research Plan. Preliminary work for a feasibility study of a polarimetry diagnostic on JT-60SA has been undertaken, using the CRONOS scenario simulations as a basis.

Operation. A joint JA-EU working group has been set up in 2012, responsible for establishing the principles, the methods and the overall structure of the JT-60SA data management, validation and analysis tools, for an efficient start of the JT-60SA operation and a direct participation of the EU physicists in the scientific exploitation of the machine. Synergies with the Remote Experimentation Center (REC) activities have been pointed out and analysed. The REC is the remote control room and communication environment (developed in the framework of the Broader Approach agreement) that will allow Japanese physicists to participate in ITER experiments from Rokkasho. The working group has produced a report with detailed recommendations, which should constitute a sound basis for the technical work aiming at providing JT-60SA with a modern data and analysis tools system, fully adapted to an internationally operated experiment. An analogous working group on the methods and procedures of the machine operation should be set up in 2014. In the long run, this activity should result in producing an operation handbook for JT-60SA.

[1] J. Garcia et al., *39th EPS Plasma Physics Conference*, P5.057. (Stockholm, July 2-6, 2012).
[2] G. Giruzzi et al., *39th EPS Plasma Physics Conference*, P5.018. (Stockholm, July 2-6, 2012).
[3] E. Barbato et al., *39th EPS Plasma Physics Conference*, P2.002. (Stockholm, July 2-6, 2012).
[4] T. Bolzonella et al., *39th EPS Plasma Physics Conference*, P4.025. (Stockholm, July 2-6, 2012).
[5] C. Sozzi et al., *17th Joint Workshop on ECE and ECRH* (Deurne, May 7-10, 2012).