Technology Collaboration Programme on the Stellarator-Heliotron Concept (SH TCP)

Annual Briefing 2018

1 Preface

1.1 Objective

The SH TCP's objective is to improve the physics base of the Stellarator concept and to enhance the effectiveness and productivity of research by strengthening co-operation among member countries. All collaborative activities of the worldwide stellarator and heliotron research are combined under the umbrella of this programme, which promotes the exchange of information among the partners, the assignment of specialists to facilities and research groups of the contracting parties, joint planning and coordination of experimental programmes in selected areas, joint experiments, workshops, seminars and symposia, joint theoretical and design and system studies, and the exchange of computer codes.

1.2 Organization

The joint-programming and research activities are organized via the Coordinated Working Group Meetings (CWGM). The bi-annual "International Stellarator-Heliotron Workshop" (ISHW) serves as a forum for scientific exchange.

1.3 Major achievements 2018

The third operations phase (OP 1.2b) of Wendelstein 7-X (W7-X) and the second Deuterium experimental campaign of the Large Helical Device (LHD) mark the highlights of 2018. The operations phase OP 1.2b was successfully concluded in October 2018 and first results presented at the 27th IAEA Fusion Energy Conference and the 60th Annual Meeting of the APS Division of Plasma Physics received considerable attention. The 20th LHD campaign commenced in October 2018 and will last until February 2019.

2 Chair's Report

2.1 Main events

2.1.1 17th Coordinated Working Group Meeting (CWGM)

The 17th Coordinated Working Group Meeting (CWGM17) was held on 6 October 2017 in Kyoto. The agenda was designed as a follow-up of the previous 16th CWGM and included discussions of on-going intensive collaborations on the following topics: Transport modelling, energetic particles/AEs control; impurity transport (mainly on TESPEL injection); core electron-root confinement; turbulence/isotope effect. Several joint actions and joint publications were initiated. For the purpose of strengthening the links to the ITER International Tokamak Physics Activity (ITPA), brief updates on recent activities of the topical groups were given by the ITPA members present at the meeting.

2.1.2 18th Coordinated Working Group Meeting (CWGM)

The 18th CWGM was held in Princeton, New Jersey (United States) from April 10th-12th 2018. Representatives from 14 institutions and 9 countries attended the meeting. Numerous joint activities and responsible persons were identified on the following topics: Divertor physics, W7-X scraper elements; 3D turbulence, isotope effect; database progress and ITPA links; impurity transport; core electron root confinement; plasma terminating events by excess fuelling and impurities; wall conditioning; fuelling and pellet injection.

2.2 Milestones achieved

2.2.1 Deuterium campaign at LHD

The second deuterium campaign (20th campaign) of LHD started on October 23, 2018, to be continued until February 21, 2019. The 4 topical groups (TGs) will examine: high-performance plasma, transport and confinement, edge/divertor/atomic and molecular processes, and high-beta/MD/energetic particles, are formulated to conduct experiments with participations of international and domestic collaborators. The 3rd International Program Committee meeting was held on September 19, 2018, to share and discuss on the main goals of the 20th campaign such as, maximize and integration of performance, isotope effects, increase understanding on edge and divertor plasmas to be extrapolated to reactor-relevant regime, extension of high-beta plasmas in low-collisional and high field regime, and further extend the energetic particles physics study.

2.2.2 NIFS Cooperation with SWJTU on a Quasi-axisymmetric Stellarator

The NIFS-SWJTU (Southwest Jiaotong University, China) have proceeded programmatic physics and engineering study on the joint project, CFQS (Chinese First Quasi-axisymmetric Stellarator), of which results have been presented in many occasions (EPS, International Toki Conference, etc.). The first plasma is foreseen in 2021.

2.2.3 Milestones from TJ-II

The programme of the TJ-II stellarator focused mainly on: Modelling and validation of impurity transport, validation of gyrokinetic simulations, turbulence characterisation, effect of magnetic configuration on transport, fuelling physics with pellet injection, fast particles and liquid metal plasma facing components. This included the effect of plasma drifts on the collisional (neoclassical) plasma transport, gyrokinetic simulations of plasmas which were fuelled by cryo-genic pellets, the impact of radial electric fields on plasma turbulence in the plasma edge and scrape-off layer. Research on the physics and modelling of plasma core fuelling with cryogenic fuel and impurity pellets has produced new relevant results. Finally, alternative plasma facing components based on liquid metals are under investigation.

2.2.4 Wendelstein 7-X Campaign OP 1.2b

The third experimental campaign of Wendelstein 7-X took place from July to October 2018. The experiments used electron cyclotron resonance heating (ECRH) with a maximum power of ~ 7 MW, which is the highest ECRH power ever employed in a fusion experiment. Later in the campaign, neutral beam injection (NBI) with up to 3.6 MW was tested for the first time on Wendelstein 7-X. This included first studies of fast ion confinement and the losses of fast ions. The scientific program focused on the demonstration of stationary, high performance discharges and the characterization of the inertially cooled test divertor in preparation for operation of the actively cooled high heat-flux divertor in the later campaigns.

Increasing the density in hydrogen plasmas was achieved reliably by improving the wall conditioning using boronization. It was demonstrated that high plasma densities can be reached with a transition of the microwave heating power from X2-polarization to full power O2-polarization which is necessary to exceed the X2 cut-off density. At 5 MW heating power discharge lengths could be considerably improved from a few seconds in the previous campaign to a maximum of 25 seconds with stationary conditions. Sustaining a plasma over such a long time without any active divertor cooling was only possible, because the so-called detachment – a state where the plasma recombines before it reaches the divertor target – reduced the heat flux to the divertor to negligible levels.

Under various conditions triple products (the value important to achieving a burning plasma, namely the product of ion density, ion temperature and energy confinement time) were reached that were well within the range of medium-sized tokamaks.

2.3 Future Plans

2.3.1 W7-X

After the successful completion of the operations phase OP 1.2b, Wendelstein 7-X is now in its final completion phase towards steady state capability. The completion phase CP 2 is planned to last from October 2018 until early 2021 and consists of the installation of several major components, notably the actively cooled high-heat-flux (HHF) divertor, including its complex cooling water supply, and extensive measures to protect the in-vessel components against high heat loads. Additionally, the NBI and ICRH-heating systems will be extended to their full capability and the set of diagnostics will be expanded. It is also intended to develop long-pulse Gyrotrons with a new record power output of 1.5 MW.

The operations phase OP 2 will follow a staged approach, consisting of several energy steps from 1 GJ to 18 GJ. The creation of long-pulse, high performance plasmas with 30 minute pulse length and 10 MW heating power is intended to be achieved during the operations phase OP 2.3 in the years 2023/2024.

For improved fuelling and density control, a project to build and install a continuous (10 Hz) repeating pellet injector for use in long pulse W7-X experiments in OP 2 from late 2020 is being jointly pursued between US partners (Oak Ridge National Laboratory, Princeton Plasma Physics Laboratory) and Germany (Institute for Plasma Physics, Garching) and has received initial funding from the US department of energy.

2.3.2 Participation

Internal deliberations within the government of Costa Rica have delayed the accession of Costa Rica to the SH TCP. However, the Costa Rican counterpart has underlined the intention to join the TCP and to submit the necessary paperwork in early 2019.

In order to facilitate the accession of Chinese institutions to the TCP, an overview presentation of the Chinese stellarator activities was given by Prof. Xu during the 2018 ExCo meeting. A planning meeting with the potential partners will be held in the spring of 2019.