# Technology Collaboration Programme on the Stellarator-Heliotron Concept

# (SH-IA)

Annual Brief 2016

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# 1 Preface

Established in 1985, the Stellarator-Heliotron Technology Collaboration programmes objective is to improve the physics base of the Stellarator concept and to enhance the effectiveness and productivity of research and development efforts related to the Stellarator concept 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 continues to promote 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. The research activities within the TCP are organized via the Coordinated Working Group Meetings (CWGM). The bi-annual "International Stellarator-Heliotron Workshop" serves as an important forum for the scientific exchange within the scientific community.

While the main development line in fusion research is the tokamak line, stellarators and heliotrons constitute a promising alternative with advantageous properties, such as steady-state confinement with the prospect of developing a more economic power plant concept. A major strategic objective is the development of the physics and technology basis for a fusion demonstration power plant. Based on the enhancement of physics understandings and accumulated experimental database, conceptual reactor designs have progressed, based on Stellarator-Heliotron concepts.

However, it has also become evident that the understanding of the more complex three-dimensional confinement properties of stellarators and heliotrons is indispensable for the further development of tokamaks. The promotion of the synergies between tokamaks and stellarators and heliotrons is therefore a central part of the strategic direction of the TCP. An important mechanism to foster such synergies is the participation of a representative of the Stellarator-Heliotron TCP in each topical group of the International Tokamak Physics Activity (ITPA).

# 2 Chair's Report

## 2.1 Main events

### 2.1.1 20th International Stellarator-Heliotron Workshop (ISHW)

The 20th International Stellarator-Heliotron Workshop took place October 5 – 9, 2015 in Greifswald, Germany. 215 participants from five continents gathered to exchange the latest information about progress in the science of plasma confinement in non-axisymmetric magnetic fields. The workshop consisted of one overview session and six topical sessions, with 31 invited papers, 36 oral contributions and 116 poster presentations. Results were published as a special issue of Plasma Physics and Controlled Fusion (Vol. 58, 2016), and a summary can be found in issue 151 of the Stellarator News (December 2015; http://web.ornl.gov/info/stelnews/pdf/sn150.pdf).

### 2.1.2 15th Coordinated Working Group Meetings (CWGM)

The 15th Coordinated Working Group Meeting was held in Greifswald from 21–23 March, 2016. The meeting implements the world-wide cooperation in the field of stellarators and heliotrons. The main vehicle is the International Stellarator-Heliotron Profile Database which

successively broadens the documentation of experimental results relevant to the design of next step devices. Priorities are given to topics which need to be resolved for next step developments.

For the first time, a group of coordinators prepared the meeting, identified topics for international cooperations and took over the responsibility to track the agreed actions. Specific sessions were conducted on W7-X, which had concluded its first operations campaign two weeks earlier, and comparative plasma start-up studies, impurity transport, fueling and particle transport, Alfvén Eigenmodes and turbulence optimization. Beyond specific scientific discussions, strategic cooperations have been agreed on Plasma Wall Interaction studies and diagnostics developments. A report was published in issue 153 of the Stellarator News (June 2016, http://web.ornl.gov/info/stelnews/pdf/sn153.pdf). The follow-up meeting will be conducted in January 2017 in Madrid.

### 2.1.3 45th Executive Committee Meeting

The 45th ExCo meeting took place on Oct. 20, 2016 on the site of the 26 IAEA Fusion Energy Conference in Kyoto, Japan. For the first time, a representative from Costa Rica attended the meeting as a guest, after the ExCo had agreed to start discussions on Costa Rica's participation in the TCP.

## 2.2 Milestones achieved

### 2.2.1 First W7-X Operations Phase

After the first light of Wendelstein 7-X in December 2015, the operations campaign was continued with extraordinary success until March 10, 2016. The first weeks of operations with helium were mainly used to commission the diagnostics and heating systems, to test the device control and to condition the first wall. A milestone was the creation of the first hydrogen plasma on February 3 in the presence of the German Chancellor Angela Merkel. The event has received considerable attention not only from the scientific community, but was also prominently covered by the international media. The many positive reports about the successful start of W7-X had noticeable impact on the public image of fusion research and the prospects of fusion as a future energy source.

With plasma parameters up to 10 keV electron temperature at densities between 2 and 3 · 1019 m-3, the initial expectations were greatly exceeded. The discharge lengths were gradually extended from 50 msec to 1 sec. at 4 MW heating power and up to 6 sec. at 500 kW heating power. During the six weeks of hydrogen operation a fruitful physics research programme was conducted: the assessment of power balance and energy confinement, investigation of impurities and their transport, heat load distribution on the inboard limiters, and advanced plasma wave heating and current drive schemes.

Since the successful start of plasma operations on W7-X, after 15 years of construction, a new and exciting fusion research facility has become available to the stellarator community.

Together with the IPP home team, researchers from EUROfusion consortium members, Australia, Japan and the USA have worked together during the 10 weeks of plasma operations. As

a result of the so called “one team approach”, a large majority of the 774 scientific proposals came from multiple international contributors

### 2.2.2 Final Preparations for Deuterium Campaign on LHD

The preparation of the deuterium campaign on LHD has made great progress and first deuterium plasmas are early March 2017. This is an important step not only for LHD but for the entire stellarator community since it will not only enhance the performance of LHD but allows addressing key scientific questions like the isotope effect in confinement and transport. This will establish an important data basis for comparative experiments with deuterium plasmas in W7-X starting in 2020.

## 2.3 Future Plans

The inauguration of the superconducting stellarator W7-X has created the opportunity for collaborations on a wide range of inter-machine comparisons, most prominently between W7-X, LHD, HSX, Heliotron-J and TJ-II, but also with leading tokamak devices in the world. A common ground for collaboration continues to be the joint development of diagnostics, which will be further intensified. The links between W7-X and the Japanese partners will be strengthened through several new cooperation projects; the same holds true for the partnership between W7-X and the EUROfusion consortium, the United States and Australia. After further extensions towards steady-state capability of W7-X, the key issue of long pulse operation with fusion relevant plasmas will be jointly addressed by all cooperation partners. An intermediate step will be made during the 2017/2018 operations phase of W7-X where 10 sec high performance plasmas become possible by means of an intertially cooled island divertor.

Another major milestone will be the first deuterium campaign on LHD, beginning in March 2017, which is planned to last until July/August of 2017. Deuterium operation of LHD will provide important insights into the transport physics of heliotrons and stellarators, thereby establishing a reference case for deuterium operations on W7-X starting 2020. An international programme committee has been formed and a strong international participation is expected.

Joint studies on stellarator/heliotron-based fusion power plants are intended to put further emphasis on engineering aspects e.g. blanket remote handling and wall loads, but also on cost aspects.

The discussions with Costa Rica regarding their future participation in the TCP will be continued.

The recent signing of the association agreement between EUROfusion and Ukraine and the allocation of an indicative budget have created new prospects for a further strengthening of the collaboration with Ukraine through its active participation in the EUROfusion stellarator work packages. Discussions have started on future joint activities and the incorporation of Ukrainian researchers in the EUROfusion work packages.

The next meetings of the CWGM will be in Madrid, Spain in January 2017. The 2017 meeting of the International Stellarator-Heliotron Workshop (ISHW) will be held in October in Kyoto, Japan, with the next ExCo meeting in the frame of the workshop.