Technology Collaboration Programme on the Stellarator-Heliotron Concept

(SH-TCP)

Annual Report 2016
(Full Report)

Table of Contents

1 Preface

Established in 1985, the Stellarator-Heliotron Technology Collaboration programs 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.

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 crucially 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.

Follow-up meetings will be conducted in January 2017 in Madrid and later in Princeton. A report was published in issue 153 of the stellarator news (June 2016, http://web.ornl.gov/info/stelnews/pdf/sn153.pdf).

2.1.3 45th Executive Committee Meeting

The 45th ExCo meeting took place on Oct. 20, 2016 on the site of the 26th 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 have 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 $\cdot$ 10^{19} 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 program 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 were proposed by 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 after 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 and in Princeton, USA in March. 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.

3 Membership

3.1 Contracting Parties and ExCo Members

Contracting party	Country	Name	Affiliation
ANU	Australia	B. Blackwell	The Australian National University
		J.H. Harris	The Australian National University
EURATOM	Germany	R. Wolf (Chair) T. Klinger (alternate)	Max-Planck-Institute for Plasma Physics
	Spain	J. Sanchez C. Hidalgo (alternate)	CIEMAT
NIFS	Japan	Y. Takeiri (Vice Chair)	National Institute for Fusion Science
		T. Morisaki	National Institute for Fusion Science
ROSATOM	Russia	B. Kuteev	National Research Center, Kurchatov Institute
		V. Ivanov	Prokhorov General Physics Institute of Russian Academy of Sciences
NSC	Ukraine	I.E. Garkusha	Institute of Plasma Physics, National Science Center "Kharkov Institute of Physics and Technology"
		V.S. Voitsenya	Institute of Plasma Physics, National Science Center "Kharkov Institute of Physics and Technology"
US DOE	USA	D.T. Anderson	Wisconsin University
		D. Gates *(since Dec. 1, 2016)*	Princeton Plasma Physics Laboratory
		M.C. Zarnstorff (Vice Chair) *(until Nov. 30, 2016)*	Princeton Plasma Physics Laboratory
Observers		C. Pottinger	IEA
		L.G. Eriksson	European Commission
		T. Mutoh (SSOCG Co-Chair)	National Institute for Fusion Science
		I. Vargas Blanco *(since Oct. 20, 2016)*	Costa Rica Institute of Technology
		M. Yokoyama	National Institute for Fusion Science
		P. Kurz (Secretary)	Max-Planck-Institute for Plasma Physics

3.2 Countries targeted to join

The ExCo has agreed to start discussions on Costa Rica’s participation in the TCP.

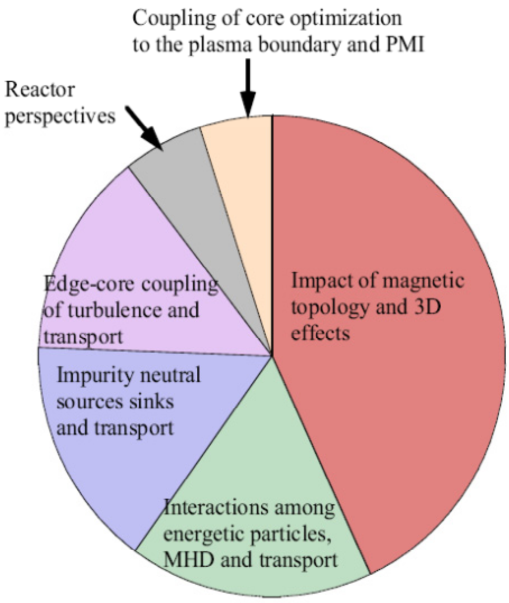
4 Meetings

4.1 International Stellarator-Heliotron Workshop (ISHW)

The 20th International Stellarator-Heliotron Workshop was held 5–9 October 2015, at Greifswald, Germany. The Max Planck Institute for Plasma Physics hosted this workshop, which was planned to take place against the background of upcoming experiments in Wendelstein 7-X. The workshop was held at the Alfried-Krupp-Wissenschaftskolleg, which is located in the Centre of Greifswald. Head of the International Programme Committee was Prof. Katsumi Ida, National Institute for Fusion Science, Toki, Japan, and head of the Local Organizing Committee was P. Helander, IPP, Greifswald, Germany.

This workshop consisted of 1 overview session and 6 topical sessions. The topics of this workshop are listed below and the distribution of presentations is shown graphically below.

- Overview (4 invited).
- Impacts of magnetic topology/three-dimensional (3D) effects (6 invited, 8 orals, 56 posters).
- Edge-core coupling of turbulence and transport (6 invited, 8 orals, 56 posters).
- Interactions with energetic particles, MHD, and transport (6 invited, 8 orals, 56 posters).
- Impurities, neutral sources and sinks, and transport (3 invited, 4 orals, 16 posters).
- Reactor perspectives (3 invited, 4 orals, 16 posters).
- Coupling of core optimization to the plasma boundary and plasma-materials interaction (3 invited, 4 orals, 16 posters).



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/sn151.pdf).

The 21st International Stellarator-Heliotron Workshop will be hosted by the Heliotron J group of the Institute of Advanced Energy at Kyoto University and will take place October 2-6, 2017 in Kyoto, Japan. The International Programme Committee is chaired by C. Hidalgo (CIEMAT, Spain). Chair of the LOC is T. Mizuuchi (IAE, Kyoto Univ., Kyoto, Japan).

Website: http://www.center.iae.kyoto-u.ac.jp/ishw2017/

4.2 Coordinated Working Group Meetings (CWGM)

The 15th Coordinated Working Group Meeting has been held in Greifswald from 21–23 March, 2016. The meeting implements 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 crucially 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. Given that the first experimental campaigns of Wendelstein 7-X (W7-X) ended only 2 weeks prior to the meeting, a session about first findings on W7-X attracted large attention from the about 20 external participants on site. Session attendees from the host institute and many remote participants (Japan, USA, Ukraine, EC) added up to about 50 colleagues attending the meeting in total.

Specific sessions were conducted on W7-X 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 hosted by CIEMAT and is scheduled for January 18-20, 2017 in Madrid, Spain (http://fusionsites.ciemat.es/cwgm16/).

4.3 Executive Committee (ExCo) meetings

The annual meeting of the Executive Committee took place on Oct. 20, 2016 at the venue of the 26th IEA Fusion Energy Conference (Kyoto, Japan). The committee welcomed D. Gates as a new US representative in succession of former vice chair M. Zarnstorff. Also, the ExCo unanimously re-elected R. Wolf as chair and Y. Takeiri as vice chair. The ExCo appointed C. Hidalgo as the chair of the 2017 ISHW International Programme Committee and unanimously decided to start discussions with Costa Rica on their participation in the TCP.

5 Communication Efforts

5.1 Highlights from Spain

Contributed oral presentation, 43rd European Physical Society Conference on Plasma Physics, *Leuven, Belgium*, 2016. J L Velasco and the TJ-II Team (CIEMAT).

Study of neoclassical transport and zonal-flow-damping properties of non-axisymmetric configurations in perturbative experiments, concluding:

a) Pellets that do not reach the magnetic axis may still be able to mitigate core depletion, based on the radial redistribution of particles can be understood qualitatively from neoclassical predictions [J.L. Velasco PPCF-2016]

b) Observation of oscillatory radial electric field relaxation following pellet injection in a helical plasma, in agreement with GK simulations. [A. Alonso et al., Phys. Rev. Lett-2016 submitted].

Invited talk 21st Joint EU-US Transport Task Force Meeting - Leysin (Switzerland), from 5-8 September 2016. Arturo Alonso (CIEMAT)

3D effects on core and edge transport: Parallel impurity dynamics in stellarators [A. Alonso et al., PPCF-2016]

5.2 Highlights from Japan

National Institute for Fusion Science (Japan) and The University of Wisconsin-Madison, College of Engineering concluded the Memorandum of Understanding (MoU) on September 2016. This was triggered by NINS (National Institutes of Natural Sciences) / NIFS Strategic International Research Interaction Acceleration Initiative.

The main aims of this MoU are to promote cooperation between two institutions, to expand scholarly ties, to facilitate academic cooperation and promote mutual understanding.

In preparation for establishing a formal framework for future activities, both parties will:

- consult faculty, departments, and centers to explore potential mutually beneficial research, applied research, and community-based research projects;
- encourage units to explore the feasibility of activities such as student exchanges and faculty exchanges for research, lectures, and discussions that mutually benefit both institutions; and
- investigate outside funding sources for projects determined to be mutually beneficial to both institutions.

5.3 Highlights from Germany

The start of operations at Wendelstein 7-X and the first H-Plasma on February 3, 2016 attracted considerable public interest. The live-stream of the ceremony for the first H-Plasma was followed by 34.000 users online and another 1.3 Million accessed the records in the following weeks. About 2000 press articles covered the events in the national and international print media and, in addition, a good 600 online reports were published. Also, all major national and a considerable number of international TV and radio news outlets broadcasted reports. A “Science Magazine” video on the construction of W7-X was viewed more than 1.8 Million times, and received more than 5000 shares on YouTube. On Facebook and Twitter, more than 200.000 users were reached with posts on the first plasma. Other social media initiatives include an “Ask me Anything (AMA)” on reddit, with about 200.000 live visitors (https://redd.it/46k5y4). Wendelstein 7-X was also named winner in the category “Science” of the national “Landmark in the Land of Ideas” contest.

In October 2016, Wendelstein 7-X was included in the G7 Group of Senior Officials “List of Research Infrastructures of Global Interest”.

6 Activities and Outcomes

6.1 Australia

In response to a growing domestic interest in materials science for fusion, the focus of experimental research in the Australian Plasma Fusion Research Facility has been moving towards plasma materials interaction. Due to changes in staffing and funding this change will be completed in FY2016-17 with the decommissioning of the H-1 Heliac after 25 years of operation. It is hoped that H-1 may be relocated elsewhere in the world to continue its success in research, graduate training and diagnostic development. Experimental stellarator research will continue via international collaborations such as those following. The substantial infrastructure of H-1 will be redeployed on a new materials and basic plasma physics linear device based on the MAGPIE prototype. The first stage of this, the 40kW helicon plasma source, is under construction, with commissioning to begin in the next few months.

The main international experimental collaborations this year were with LHD (mm wave scattering) and Wendelstein 7-X (limiter probe array) and the Kharkov group. This collaboration, with Dr. Moiseenko resulted in the design and installation of a 'compact Alfven antenna', which has been operated in H-1 to 50kW so far. A data mining collaboration with the Heliotron J and LHD groups has been extended to include W7-X and DIII-D, including publication of a two-part tutorial paper. A collaboration with Auburn University has begun on the application of coherence imaging to stellarators.

Theoretical collaborations between the Plasma Theory and Modeling group and the IPP Theory Group focused on continuum damping and mode drive mechanisms in stellarators. The ongoing collaboration with Princeton Plasma Physics Laboratory on further development of the new 3-D equilibrium code 'SPEC' produced several papers. This collaboration will continue in 2017 with the award of a 3 year research grant to extend the multi-region relaxed MHD approach, used in SPEC, from equilibrium to dynamical calculations.

6.2 EURATOM: Germany

6.2.1 Wendelstein 7-X Operations

After the technical commissioning of Wendelstein 7-X, which was successfully completed by applying 2.5 T (average) magnetic field, and verifying the magnetic field topology which also demonstrated a very low level of magnetic field error [1], plasma operation was started in December 2015. Initially, helium was used as the main plasma constituent, followed by hydrogen plasmas in February 2016. Until 10th March 2016, ten weeks of plasma operation were possible.

The initial task was to condition the plasma vessel, thus extending the duration of the plasma discharges from initially 10 ms to several seconds. This was achieved by successively applying short pulses of heating power and also, once available, longer periods of glow discharge cleaning. Although reasonable discharge lengths could be achieved, repeatedly occurring outgassing events of the plasma facing components remained an issue throughout the campaign. Considering that a large fraction of the plasma facing components was not covered with protection tiles in this first campaign, such a behavior may not be so surprising. For the spatial limitation of the plasma, five so-called inboard limiters were used. As the limiters, which were not cooled, had to dissipate a major part of the heat coming from the plasma, the initial discharge length was limited to 2 MJ of injected energy. After it became clear that the limiters did not overheat, this level was raised to 4 MJ. As a result, the longest plasma discharges achieved at moderate heating powers (starting at 1 MW and dropping to

600 kW) lasted up to 6 sec, reaching an injected energy of 4 MJ with stationary central electron and temperatures of T_e = 5 keV and T_i = 1.5 keV at central densities of several times 10^{19} m^{-3}. In shorter plasma discharges with higher heating powers (up to 4.3 MW) plasma temperatures achieved values up to T_e = 5 keV, T_i = 1.5 keV.

During this first experimental campaign only one plasma heating system was available. Six micro-wave tubes (so-called gyrotrons) provided up to 4.3 MW launched into the plasma, generating and heating the plasma by electron cyclotron resonance absorption. The integral commissioning also included a large set of plasma diagnostic systems [2], many of which delivered data from the start. At the end of the campaign more than 30 plasma diagnostics were commissioned and provided data. Underlying all these systems was a sophisticated control and data acquisition system, which allowed operating Wendelstein 7-X in a very flexible way and provided data storage and data access for all relevant measurements.

While Wendelstein 7-X already during the construction phase relied on many contributions from partners within the Helmholtz Association, from Europe and from international collaborations, the value of this collaboration network became particularly apparent during the first experimental campaign. Examples are the development, construction and installation of the micro-wave heating system which has been implemented in the framework of a major collaboration between KIT, IPP and University of Stuttgart. FZJ provided a large number of measurement and diagnostic systems, including a mid-plan manipulator for exposing probes and samples to the plasma, a correlation reflectometer and surface analysis tools for characterizing the effects plasma wall interaction on plasma facing components. Many members of the EUROfusion Consortium are making major contributions to diagnostics, future heating systems development and the scientific program of Wendelstein 7-X, in addition to the financial support of the Consortium covering 20% of the operational costs. Major international partners are the US, Japan and Australia providing hardware and scientific expertise by sending experts who participated in the first experimental campaign. The international character of the Wendelstein 7-X operation is also reflected in number of experimental proposals from Europe and the US. Of the 774 proposals in total, 417 came from Europe (including the Helmholtz partners), 249 from the US and 108 from IPP. In 2015 an International Program Committee was established which for the next experimental campaign, scheduled to start in late summer 2017, will be responsible for selecting the proposals and approving the scientific program of Wendelstein in 7-X. For organizing the next experimental campaign four task forces have been established with altogether eight taskforce leaders, four of whom are from collaboration partners (from FZJ, Belgium, Spain and the US).

Important physics studies during the first operational campaign of Wendelstein 7-X [3, 4] include a first characterization of the plasma confinement, the understanding of the power balance, the effect of the magnetic field configuration on the heat load distribution on the plasma limiters, an assessment of the external error fields on the heat load distribution, the influence of externally driven currents on plasma transport and stability, and the first exploration of heating schemes for higher plasma densities which are required to achieve the expected optimized performance of Wendelstein 7-X. Although the plasma facing components were not complete and their conditioning was not optimal, confinement times have been achieved which agree with the scaling derived from the international confinement data base. The transport properties can be theoretically understood as a result of the very special conditions resulting from high electron temperatures, low ion temperatures and low plasma densities.

In the future the scientific programme will be approved by the International Programme Committee. 50% of the members of the IPC are representatives of the major collaborators. For the preparation of the next W7-X campaign the IPC selected 8 taskforce leaders for 4 taskforces. Of the 8 TFLs three are from EUROfusion and one is from the US. A call for experimental proposals will be sent out soon. Early March 2017 a programme workshop will be organized in Greifswald to discuss the programme of the next experimental campaign, scheduled to start end of July 2017.

[1] **T. Sunn Pedersen** at al., *Confirmation of the topology of the Wendelstein 7-X magnetic field to better than 1:100,000*, Nat. Commun. 7 (2016) 13493

[2] **M. Krychoviak** et al., *Overview of diagnostic performance and results for the first operation phase in Wendelstein 7-X*, Rev. Sci. Instrum. 87 (2016) 11D304

[3] **T. Klinger** et al.,*Performance and properties of the first plasmas of Wendelstein 7-X*, Plasma Phys. Control. Fusion 59 (2017) 014018

[4] **R. C. Wolf** et al., *First plasma operation of Wendelstein 7-X*, 26th IAEA Fusion Energy Conference, Kyoto, 2016, OV/3-1, nucleus.iaea.org/sites/fusionportal/Shared Documents/FEC 2016/fec2016-preprints/preprint0630.pdf (submitted to Nucl. Fusion)

6.2.2 Status of Wendelstein 7-X Completion

The project Wendelstein 7-X has been revamped to match the requirements of the interplay between device completion and operation phases. The goal of the project is to make Wendelstein 7-X steady-state capable at high heating power from 2020 onwards. Currently the completion phase CP 1.2 (to prepare the operation phase OP 1.2) is running. Its major work packages are the following: (1) installation of 10 inertially cooled divertor modules, (2) coverage of the wall protection shields with in total 6000 graphite tiles, (3) installation of the H+ NBI system (in total 7 MW), (4) installation of the ICRH system (in total 2 MW), (5) extension of the ECRH system (in total 8 MW), (6) installation of further ~ 30 diagnostic systems and extension of numerous existing ones, (7) extension of the periphery, (8) extension and improvement of the control and data acquisition systems. The CP 1.2 is massive and requires two-shift work on six days per week. The works are more or less running according to schedule. The assembly of the upper five divertor modules, including the baffles, is completed and the lower five divertor modules are in progress. The installation of the graphite tiles has started including scanning of the as-built geometry, 3d customizing of mismatching tiles, cleaning and baking at >500°C. The local commissioning of the first NBI box will start soon and it can be expected that at least one NBI box goes into operation during the next operation phase OP 1.2. Eight gyrotrons for ECRH are installed and ready to operate. The ICRH works run according to plan. The majority of the diagnostics are expected to be available for assembly and integration at the end of the year. Very time critical is the necessary extension of the control, data acquisition and data storage systems. Here, personnel reinforcements as well as managerial measures have been implemented to safeguard the timely start of OP 1.2. From the present perspective, a start of plasma operation in July 2017 seems feasible.

During construction of Wendelstein 7-X, significant efforts have been made to ensure Paschen-tightness of the complete magnet system, including the actual coils, the bus bar system, the joints, and the current leads. Before cool-down, the Paschen-tightness at 2.5 kV was confirmed. After first operation of Wendelstein 7-X (OP 1.1) and subsequent warm-up, it was found that Paschen-tightness for the circuits of coil types 3 and 4 is lost: There are (current limited) breakthroughs observed at about 1 – 1.5 kV, depending on the background gas pressure. After careful assessment of the case, it was decided to operate the coils if (a) the high-voltage insulation is proven under cold conditions, where high vacuum conditions are given, (b) the monitoring of coil operation and cryostat vacuum is extended and refined, (c) strategies for localization of the insulation weakness and possible repair scenarios are developed in parallel.

6.2.3 Status of EUROfusion

The EUROfusion consortium meanwhile has established a routine modus vivendi.

The EUROfusion Roadmap is being updated at present. The successful start of W7-X gave additional momentum to establish a stronger role of stellarator research in the future EUROfusion programme.

6.3 EURATOM: Spain

6.3.1 Highlights TJ-II research programme

Impurity transport and asymmetries on magnetic flux surfaces

The break of axisymmetry causes that NC transport is not automatically ambipolar, giving rise to the onset of a radial electric field, which has strong influence on particle transport and fuelling. Impurity transport is also affected and we have explored the conditions in which the inwards impurity pinch is decreased and allow that other transport terms can decrease impurity accumulation. The first order NC theory predicts the existence of asymmetries on the magnetic surfaces, which have been observed experimentally in TJ-II, and can have strong influence on impurity transport.

Particle fuelling and Neoclasical effects

Experimental observations and NC calculations study show central plasma density depletion in low collisionality plasmas, which is a problem detected in helical devices. We have shown that this can be overcome by injecting a pellet, even it is ablated before reaching the plasma centre. Pellet injection has not been only used as fuelling tool, but it has allowed us to obtain for the first time a direct observation of the electric field relaxation, in agreement with GK simulations. Another important characteristic of the fuelling in TJ-II is the structure of the neutrals that reflect the blobs that are found in density turbulence.

Plasma-wall studies

Plasma wall interaction in TJ-II depends strongly on the 3D geometry and makes TJ-II a well-suited laboratory to explore innovative solutions for plasma facing components based on the use of liquid metals like Li and SnLi alloys.

Stability studies and 3-D magnetic configuration effects

We have obtained stable plasmas in theoretically Mercier-unstable configurations and have found that the confinement depends rather on NC properties and volume than on Mercier criterion. Firm candidates to EGAMs driven by fast ions and fast electrons are also detected in TJ-II, showing the effect of rational values of the rotational transform on the latter modes.

MHD stability and the magnetic island onset have strong influence on momentum transport and on L-H transition. Low order rational values of the rotational transform ease the formation and destruction of transport barriers, thus playing a key role in confinement transitions. These works are the base for rotational transform-based control techniques of confinement regimes.

Fast particle physics

The dispersion relation of AEs is affected by the 3D geometry. In particular, we have shown that the magnetic well is a governing parameter of the frequency of the mode: the larger the well, the higher the frequency, for the same density. The rotational transform plays a key role in the AEs properties: we have found the rotational transform windows in which the mode presents a chirping nature and the ones in which its frequency varies steadily following plasma current and density. Locked islands associated to rational values of the rotational transform open gaps in the Alfvén continuum that would not exist otherwise (MIAE). This poses the magnetic configuration as another important tool for controlling AEs and, hence, fast ion confinement beyond ECRH. New experiments show that the amplitude of the chirping AE mode increases while the bursts periodicity becomes more regular, as the ECRH power increases.

The TJ-II research programme is developed in the framework of a long-standing international collaboration:

6.3.2 Collaborations with Japan

TESPEL and plasma fuelling collaborations

A TESPEL system, developed by NIFS, has been operated on TJ-II in 2015. Based on that experience and on the TJ-II experience with the pellet injector developed by ORNL, we plan to reinstall the TESPEL system (2016/17) to further develop the on-going particle/impurity transport programme on TJ-II supporting W7-X.

Fast particle physics

Joint experiments with emphasis on the influence of ECRH and plasma configuration effects on AEs in TJ-II (NIFS and Kyoto Univ).

Joint experiments on island dynamics in LHD / TJ-II

First experiments and analysis on the use of ECCD techniques (LHD) support the possibility of externally controlling width and phase of static Resonant Magnetic Perturbations of interest for the control of island divertors.

Isotope effect physics

Isotope physics supporting the LHD research programme.

Neoclassical effects

Studies on the moderation of neoclassical impurity accumulation in high ion temperature plasmas of LHD helical device showed that weak radial electric field is a characteristic and relevant feature of impurity hole plasmas. Isotope effect and parameter dependence of the radial electric field will be studied and compared with data available in the International Stellarator-Heliotron Database (2017).

Edge physics

Collaboration on edge transport studies using fast visible cameras in TJ-II / LHD (NIFS). Collaboration with Kyoto University and NIFS on edge biasing experiments and physics of plasma bifurcations.

6.3.3 Collaborations in Europe

Germany

W7-X OP 1.1 / OP 1.2 research programmes

The CIEMAT team is involved in the development of the Doppler reflectometry system installed in W7-X (OP1.1 / 2016). A dual reflectometry system is under development in view of the OP1.2 experimental campaign. The CIEMAT team will participate on different OP1.2 / 2017 task force areas, including Plasma Heating, Fuelling and Current Drive / Transport and Stability (Arturo Alonso TF) / Scenario Integration. CIEMAT will participate in the support structure design, installation and operation of TESPEL on W7-X, currently planned for OP1.2b.

GK simulations and model validation.

GK studies (EUTERPE), linear and non-linear simulations, physics of zonal flows and impurity dynamics.

Poland

Impurity transport

Collaboration on impurity transport studies in TJ-II supporting W7-X programme. Collaboration with IPPLM on X-ray pulse height analysis diagnostic for core impurity studies in W7-X.

6.3.4 Collaborations with Ukraine and Russia

Electric fields and plasma fluctuations.

Application of heavy ion beam probe diagnostics (HIBP) for investigation of plasma characteristics from the plasma edge to the plasma core in the TJ-II stellarator. The Kharkov/ Kurchatov teams were involved in the installation and alignment of the second HIBP line in TJ-II. Experiments with the dual HIBP system with combined NBI and ECR heating have given direct experimental evidence of the influence of plasma heating on neoclassical radial electric fields, fluctuation levels and on the magnitude of the Long-Range-Correlations as proxy of Zonal Flows.

6.3.5 Collaborations with USA

Impurity transport

Collaboration on impurity transport studies in TJ-II (USCD).

Plasma-wall

Collaboration on plasma-wall studies (liquid metals) (USCD)

Stability

Collaboration on plasma stability and operational limits (PPPL).

Plasma fuelling

Pellet injector developed by ORNL is in full operation in TJ-II. ORNL has continued to support upgrades of this system.

Stellarator optimization

Collaboration with ORNL

6.3.6 Collaborations with Mexico

In collaboration with the "Instituto de Ciencias Nucleares" (UNAM, Mexico city) we are running MHD codes (VMEC, SIESTA) and developing theoretical studies to model and explain the well-known magnetic island dynamics in relation with transport barrier phenomenology in the TJ-II stellarator.

6.3.7 Collaborations with Costa Rica

Collaboration with ITCR (Instituto Técnico de Costa Rica) on stellarator development.

6.4 Japan

6.4.1 NIFS

Recent progress and brief introduction to the coming deuterium experiment was reported in the 26th IAEA Fusion Energy Conference (October, 2016 in Kyoto). We are preparing for 19th campaign, which will start on February 8, 2017. It will begin with hydrogen and then, deuterium plasma production will be started in March. We will continue the 19th campaign beyond April, the new fiscal year, and presently be scheduled to July/August, depending on the budget for the next fiscal year.

We have set up the LHD international program committee (LHD_IPC), to further strengthen the international collaboration and usage of LHD. The committee consist of foreign colleagues (from China, France, Germany, Italy, Korea and USA), and LHD experiment board members. We held the kick-off meeting on 21 October (during IAEA-FEC). LHD is waiting for your/your colleagues' participation to maximize the outcome.

6.4.2 Kyoto University (Heliotron J)

Improved confinement at high-density plasmas, fast ion confinement, bulk thermal confinement, MHD stability and edge fluctuation have been investigated in a flexible helical-axis heliotron, Heliotron J, with special regard to the optimization study of helical systems with spatial magnetic-axis and vacuum magnetic well. The main subjects are high-density H-mode produced by high intense gas puffing, electron internal transport barrier (eITB), isotope effect on plasma turbulence, stabilization of energetic particle driven MHD instabilities by ECH/ECCD and confinement of high energetic particles produced by ICRF, and impurity transport.

6.4.3 Cooperation with UW Madison

The National Institute for Fusion Science (Japan) and The University of Wisconsin-Madison, College of Engineering concluded the Memorandum of Understanding (MoU) on September 2016. This was triggered by NINS (National Institutes of Natural Sciences) / NIFS Strategic International Research Interaction Acceleration Initiative.

The main aims of this MoU are to promote cooperation between two institutions, to expand scholarly ties, to facilitate academic cooperation and promote mutual understanding.

In preparation for establishing a formal framework for future activities, both parties will:

- consult faculty, departments, and centers to explore potential mutually beneficial research, applied research, and community-based research projects;
- encourage units to explore the feasibility of activities such as student exchanges and faculty exchanges for research, lectures, and discussions that mutually benefit both institutions; and
- investigate outside funding sources for projects determined to be mutually beneficial to both institutions.

As a kick-off of mutual collaborations based on this MoU, joint workshop was held on 19 and 20, September, 2016 in Madison. Colleagues in Kyoto University also participated as NIFS being the hub for international collaboration as the inter-university institution in Japan.

The personnel exchange and collaborative research items were discussed.

6.5 Russia

6.5.1 L2-M Stellarator Project (IGP RAS)

MIG-3 gyrotron complex consists of two gyrotrons with recuperation of electron beam energy and two quasi-optical tracts for power transfer into vacuum chamber of focused linearly polarised microwave.

One gyrotron operates at 75 GHz frequency that corresponds to the second cyclotron harmonic at $B = 1.34$ T. Another gyrotron operates in variable-frequency regime at 71,5 GHz, 74,8 GHz and 78,2 GH.

Experiments on central plasma heating by two gyrotrons with frequencies 75 и 74.8 GHz were performed. The total power reached 0.75 MW in these experiments which corresponds to value of specific power 3 MW/m^3.

Plans for 2016 – 2017

Efficiency of ECR heating of a plasma during central and noncentral heating with power up to 1 MW in the L-2M stellarator. Studies of fast energy losses in the plasma depending on the heating power. The correlation of these losses with short-wave turbulence. Analytical and three-dimensional computer analysis of MHD instabilities in configurations of L-2M and L-5 stellarator under conditions of high-power microwave heating.

6.5.2 L5 Stellarator-activity (IGP RAS)

Parameters included in the project of the L-5 stellarator with a low aspect ratio. $B = 2$ T, $R = 96 – 101$ cm, $a_{pl} = 0.25 – 0.3$ m, $l = 2$, $M = 6$, $n_e = (0.5 – 2)x10^{20}$ m^{-3}, $T_e \sim T_i = 2 – 3$ keV, ECRH, NBI, ICRH.

6.5.3 Stellarator research in Kurchatov Institute

Main goal: the search of toroidal stellarator configurations with: good long time collisionless α-particle confinement; small neoclassic transport (small effective ripple); small bootstrap current; high equilibrium and stability β limit. The main attention is paid to quasi-isodynamic configurations

6.5.4 Collaborations with Japan

Pellet-plasma interaction and cloud physics study on LHD continue by Peter the Great Polytechnic University, St. Petersburg.

Tungsten radiation models are developed in collaboration with LHD by Lebedev Institute, Moscow.

6.5.5 Collaborations with Europe

Germany

Theoretic work on isodynamic stellarator magnetic configuration is performed by Kurchatov and Greifswald teams.

Long term collaboration on development of divertor simulators and edge plasma physics.

England, Sweden, Poland. IAEA CRP on Compact steady state fusion neutron source performed in 2013-2016 (Tokamak Energy Ltd, Uppsala University).

Collaborations with Ukraine

Kurchatov teams involved in the joint with Kharkov installation and alignment of the second HIBP line in TJ-II. The important capabilities of the dual HIBP system allow one to provide measurements from the plasma edge to the plasma core. GAM instability is investigated and compared with tokamaks.

6.5.6 Collaborations with USA

IAEA CRP on Compact steady state fusion neutron source performed in 2013-2016 (Austin University, Texas).

Collaboration activity with PPPL on divertor and lithium technology problems

6.6 Ukraine

Study of initial phase of RF discharge for plasma production in stellarator-type devices Uragan-2M and Uragan-3M.

The work was started last year together with representatives from the Laboratory for Plasma Physics, ERM/KMS, Brussels, Belgium. Preliminary results were presented in the invited talk during ICPPCF-2016 (12-15 September, Kharkov). During current experimental campaign at Uragan-3M some additional measurements in this direction are being carried out.

Optimization of RF conditioning at Uragan-2M and Uragan-3M with and without magnetic field.

Additional hardware for qualitative analysis of conditioning efficiency was put into operation at Uragan-2M, and first results with RF discharge without magnetic field were presented at the ICPPCF-2016 (12-15 September, Kharkov).

Detail study in torsatron Uragan-3M of the correlation between characteristics of divertor flows and plasma parameters in the confinement volume.

For measuring plasma parameters outside the plasma confinement volume more than 70 electrical probes (with fixed positions or movable) are installed in the vacuum chamber of Uragan-3M. This gives possibility to measure the correlation between parameters of confined plasma and plasma in divertor regions.

Study of RF plasma behavior at torsatron Uragan-2M in a combined magnetic system "magnetic mirror-stellarator", as a model of fusion-fission magnetic configuration.

It was shown in preliminary experiments that because of two systems of magnetic coils creating toroidal component of magnetic field in this machine, the magnetic configuration "mirror-stellarator" can be organized with a quite acceptable characteristics of magnetic surfaces. Existence of magnetic configuration with nested magnetic surfaces was shown by the use of electron beam – luminescence rod method. Preliminary experiments demonstrated that plasma can be produced with same RF antennas that are used in experiments with standard torsatron configuration.

Detail study of turbulent processes in torsatron Uragan-3M in low collision mode of plasma confinement.

In Uragan-3M there are several sets of electric probes that are in use for studies of plasma turbulence at the outermost plasma periphery and in near to plasma border (last closed magnetic surface). Some time ago dramatic drop of turbulence magnitude was described just at the moment of transition to H-like mode of plasma confinement. It is planned now to investigate the correlation between characteristics of turbulence and plasma parameters inside the plasma confinement volume.

Study at Uragan-2M and Uragan-3M of fast particles produced in RF plasma: mechanisms of their appearance, their confinement, and effects on excitation of Alfven and EGAM fluctuations.

An evidence of high energy tails in ion and electron distributions was showed during RF plasma production in the Uragan-3M torsatron by neutral particle analyzers and ECE, correspondingly. Now in the U-3M vacuum chamber the sets of magnetic probes are installed and recently the data were obtained indicating on existence of magnetic fluctuations in lower ($\leq$50 kHz) and high ($\leq$500 kHz) frequency ranges. The aim of future experiments is to look for correlation of appearance of high energy particles and level of fluctuation.

Provide modeling experiments at Uragan-2M and Uragan-3M on possibilities to suppress appearance of run-away electrons in ITER by the use of stationary, pulsed, or RF fields applied at the plasma periphery.

Suppressing the appearance of runaway by applying fixed potential to the electrode located near plasma periphery. In future we plan to provide comparative study with different regimes of potential supplying: stationary (both signs), pulsed, and RF.

The movable limiter made of porous tungsten is installed at Uragan-3M.

The head of limiter is made of porous tungsten, what gives possibility to make pulsed or stationary feeding of hydrogen locally, close to limiter position and without serious contamination of plasma. The limiter can be also used for providing experiments on effects of positive or negative radial electric field on plasma confinement.

6.7 USA

6.7.1 Collaborations with Germany

International stellarator collaboration activities in the US primarily focused on the initial run of W7-X in 2016. Several US staff and students/post-docs stayed in Greifswald, Germany for the bulk of the run including: 1 senior staff member from LANL (Wurden), 2 junior staff members from PPPL (Pablant and Lazerson), 3 students from the University of Wisconsin, and 1 student from Auburn University. In addition there were several week-long visits from senior staff from the US. One post-doc from UW Madison is headquartered at IPP Greifswald. Several topics of collaboration were covered including: operation of infra-red cameras for limiter temperature measurements, operation of the X-ray Imaging Crystal Spectrometer, error field measurements using the trim coils, and neutral gas characterization. Each of these topics was carried out using US supplied equipment. PPPL will also ship two TDU scraper elements this year for use during the OP 1.2b run campaign. PPPL and IPP network specialists are collaborating to implement improvements in access to W7 X data archives and web services for all U.S. partners; testing is in progress. ORNL has taken the leadership role on scraper element science campaign coordination for the US (Lore). ORNL and UW-Madison collaborated to provide filterscopes measuring absolutely calibrated hydrogen, helium, and carbon line emission in time for the first W7-X plasma discharge in December 2015 and for the entire campaign. Early experiments were simulated using the 3D transport code EMC3-EIRENE showing good qualitative agreement, with the filterscope view geometry and spectral information used to implement a synthetic diagnostic for direct comparison to measured data. Quantitative agreement required invention of a method to reconstruct the local S/XB emissivities from the synthetic model and correct the measurement for it when calculating absolute particle fluxes. The University of Wisconsin focused on collaborations in neutral pressure measurements, edge spectroscopy and on divertor modeling. UW Madison has spearheaded together with FZ Juelich the post-mortem analysis of OP1.1 limiters and comparisons to in-situ spectroscopy. The erosion/deposition pattern was resolved and are being compared to 3-D PMI modeling (collaboration with FZ Juelich). LANL has equipped one limiter with a state of the art combined IR/visible camera system involving a student from UW Madison. LANL is continuing efforts to prepare diagnostics for OP1.2 and OP2.0. In particular, a new IR/visible viewing system to monitor the scraper element, and collaborating on a design for the full OP2.0 water-cooled IR viewing system for machine protection in all five modules. Theoretical collaboration on gyrokinetics continued. Auburn University is collaborating on the XICS diagnostic in coordination with PPPL. Auburn is also working on implantation of equilibrium reconstructions using V3FIT. Work done in 2016 as part of the MIT-W7X collaboration on Gas-Puff-Imaging has involved 1) preparations to provide a fast-framing camera with a view of the W7X cross-section during OP 1.2, and 2) the design a Gas-Puff-Imaging diagnostic proposed for use during OP 2. Both of these efforts will contribute to the study of fluctuations and plasma structure in the plasma edge and in the island-divertor regions. MIT (Porkolab & Edlund) is building a phase contrast imaging diagnostic that will be operating in the OP1.2 campaign and will contribute to studies of turbulence and transport.

6.7.2 Collaborations with Japan

University of Wisconsin is collaborating on numerical and experimental projects with NIFS. Hegna is working with Narushima et al. on island healing studies in LHD – Hegna is a co-author of Narushima's IAEA presentation looking at sustained phase shifted magnetic islands relative to externally imposed m/n = 1/1 RMPs. The second activity involves comparisons between HINT and NIMROD addressing the role of anisotropic heat flux closures and their role in affecting equilibrium beta limits. Schmitz is working with Kobayashi and Ida on "Helium Exhaust with the Closed Helical Divertor at LHD". They showed enhanced helium exhaust by controlling edge stochasticity and implementing magnetic islands. Bader performed EMC3-EIRENE modeling for these experiments resolving the importance fo helium recycling in the fueling term an showing enhanced friction on the penetrating impurities with RMP fields. Schmitz gave an IAEA contributed talk on the topic and three papers have been published in 2016 (Schmitz, Bader, Ida). Pablant from PPPL is currently working on analysis of the XICS data and transport measurements for data taken in previous years.

6.8 Names of personnel participating in experiments

Contracting Party	Experiment	Name
Australia (ANU)	W7-X	Boyd Blackwell
Australia (ANU)	LHD	Clive Michael
EURATOM (Austria, OEAW)	W7-X	Roman Schrittwieser
EURATOM (Belgium, LPP-ERM/KMS)	W7-X	Tom Wauters
EURATOM (France, CEA)	W7-X	Victor Moncada
EURATOM (Germany, FZJ)	W7-X	Marion Dostal
EURATOM (Germany, FZJ)	W7-X	Nengchao Wang
EURATOM (Germany, FZJ)	W7-X	Oleksandr Marchuk
EURATOM (Germany, FZJ)	W7-X	Philipp Drews
EURATOM (Germany, FZJ)	W7-X	Shaocheng Liu
EURATOM (Germany, FZJ)	W7-X	Yunfeng Liang
EURATOM (Germany, IPP)	Heliotron J	Gavin Weir
EURATOM (Hungary, RCP Wigner)	W7-X	Gábor Cseh
EURATOM (Hungary, RCP Wigner)	W7-X	Gabor Kocsis
EURATOM (Hungary, RCP Wigner)	W7-X	Tamás Szabolics
EURATOM (Hungary, RCP Wigner)	W7-X	Támas Szepesi
EURATOM (Italy, Univ. Cagliari)	W7-X	Fabio Pisano
EURATOM (Netherlands, FOM-Differ)	W7-X	Hans Oosterbeek
EURATOM (Poland, IPPLM)	W7-X	Agata Czarnecka
EURATOM (Poland, IPPLM)	W7-X	Jacek Kaczmarczyk
EURATOM (Poland, IPPLM)	W7-X	Leszek Ryc
EURATOM (Poland, IPPLM)	W7-X	Monika Kubkowska
EURATOM (Poland, IPPLM)	W7-X	Natalia Krawczyk
EURATOM (Poland, IPPLM)	W7-X	Slawomir Jablonski
EURATOM (Poland, IPPLM)	W7-X	Tomasz Fornal
EURATOM (Poland, Opole University)	W7-X	Ireneus Ksiazek
EURATOM (Portugal, IST)	W7-X	Bernardo Carvalho
EURATOM (Spain, CIEMAT)	Heliotron J	Alvaro Cappa
EURATOM (Spain, CIEMAT)	W7-X	Alvaro Cappa
EURATOM (Spain, CIEMAT)	W7-X	Arturo Alonso
EURATOM (Spain, CIEMAT)	Heliotron J	Bing Liu

EURATOM (Spain, CIEMAT)	W7-X	José Luis Velasco
EURATOM (Spain, CIEMAT)	W7-X	José Luis Velasco
EURATOM (Spain, CIEMAT)	W7-X	Kieran McCarthy
EURATOM (Spain, CIEMAT)	W7-X	Teresa Estrada
EURATOM (Switzerland, EPFL)	W7-X	Melanie Preynas
Europe (Germany, FZJ)	W7-X	Marion Dostal
Japan (Kyoto University)	HSX	Shiji Kobayashi
Japan (Kyoto University)	TJ-II	Shinsuke Ohshima
Japan (NIFS)	TJ-II	Hiromi Takahashi
Japan (NIFS)	TJ-II	Naoki Tamura
Japan (NIFS)	TJ-II	Yoshiro Narushima
Ukraine (IPP NSC KIPT)	TJ-II	A Kozachek
Ukraine (IPP NSC KIPT)	TJ-II	A.Chmyga
Ukraine (IPP NSC KIPT)	TJ-II	A.Zhezhera
Ukraine (IPP NSC KIPT)	TJ-II	G.Deshko
USA (Auburn University)	W7-X	Peter Traverso
USA (LANL)	W7-X	Glen Wurden
USA (MIT)	W7-X	Jeff Harris
USA (PPPL)	W7-X	David Gates
USA (PPPL)	LHD	Novimir Pablant
USA (PPPL)	W7-X	Novimir Pablant
USA (PPPL)	W7-X	Samuel Lazerson
USA (UCSD)	TJ-II	Eric M Hollmann
USA (UW Madison)	LHD	Chris Hegna
USA (UW Madison)	W7-X	Florian Effenberg
USA (UW Madison)	W7-X	Laurie Stephey
USA (UW Madison)	LHD	Oliver Schmitz

6.9 List of scientist exchanges

Contracting Party	Name	Dates	Location
Australia	Adelle Wright	09/04/2016 – 09/30/2016	Greifswald, Germany
Australia	John Doe	09/22/2016 – 10/15/2016	Greifswald, Germany
Australia	Boyd Blackwell	02/20/2016 – 03/11/2016	Greifswald, Germany
Austria	Roman Schrittwieser	02/01/2016 – 02/05/2016	Greifswald, Germany
Costa Rica	Adolfo Solano Piedra	04/04/2016 – 04/29/2016	Greifswald, Germany

Contracting Party	Name	Dates	Location
EURATOM (Switzerland)	Jonathan Green	11/14/2016 – 11/18/2016	Greifswald, Germany
EURATOM (France)	Erwan Deriaz	01/31/2016 – 02/06/2016	Greifswald, Germany
EURATOM (Germany)	Axel Könies	06/26/2016 – 07/01/2016	Aix-en-Provence, France
EURATOM (Germany)	Joris Fellinger	06/17/2016 – 07/01/2016	USA
EURATOM (Germany)	Alexey Mishchenko	09/25/2016 – 10/01/2016	Madrid, Spain
EURATOM (Germany)	Gabriel Plunk	09/25/2016 – 10/01/2016	Madrid, Spain
EURATOM (Germany)	Josefine Proll	09/25/2016 – 10/01/2016	Madrid, Spain
EURATOM (Germany)	Josefine Proll	05/28/2016 – 06/03/2016	Toki, Japan
EURATOM (Germany)	Per Helander	05/31/2016 – 06/03/2016	Stockholm/Göteborg, Sweden
EURATOM (Germany)	Albert Mollen	10/20/2016 – 11/03/2016	Göteborg, Sweden
EURATOM (Germany)	Josefine Proll	03/29/2016 – 03/31/2016	Eindhoven, Netherlands
EURATOM (Germany)	Andreas Dinklage	05/28/2016 – 06/04/2016	Toki, Japan
EURATOM (Germany)	Hakan Smith	05/31/2016 – 06/04/2016	Göteborg, Sweden
EURATOM (Germany)	Hakan Smith	08/27/2016 – 09/04/2016	Varenna, Italy
EURATOM (Germany)	Joaquim Loizu	08/27/2016 – 09/04/2016	Varenna, Italy
EURATOM (Germany)	Per Helander	08/27/2016 – 09/04/2016	Varenna, Italy
EURATOM (Germany)	Jörg Riemann	04/26/2016 – 04/27/2016	Brussels, Belgium
EURATOM (Germany)	Axel Könies	03/03/2016 – 03/05/2016	Lissabon, Portugal
EURATOM (Germany)	Dmitry Moseev	01/31/2016 – 02/06/2016	Cadarache, France
EURATOM (Germany)	Per Helander	06/03/2016 – 06/06/2016	Lissabon, Portugal
EURATOM (Germany)	Felix Warmer	05/28/2016 – 06/25/2016	Toki, Japan
EURATOM (Germany)	Michael Cole	07/16/2016 – 08/07/2016	Princeton, USA
EURATOM (Germany)	Per Helander	07/11/2016 – 07/13/2016	Oxford, UK
EURATOM (Germany)	Josefine Proll	07/17/2016 – 07/23/2016	Princeton, USA

Contracting Party	Name	Dates	Location
EURATOM (Germany)	Gabriel Plunk	07/03/2016 – 07/09/2016	Leuven, Belgium
EURATOM (Germany)	Joaquim Loizu	07/03/2016 – 07/09/2016	Leuven, Belgium
EURATOM (Germany)	Josefine Proll	07/03/2016 – 07/09/2016	Leuven, Belgium
EURATOM (Germany)	Michael Cole	07/03/2016 – 07/09/2016	Leuven, Belgium
EURATOM (Germany)	Alexey Runov	11/04/2016 – 11/09/2016	Yokohama, Japan
EURATOM (Germany)	Nikolai Marushchenko	09/09/2016 – 09/20/2016	Kharkov, Ukraine
EURATOM (Germany)	Aleix Puig Sitjes	09/18/2016 – 09/23/2016	Budapest, Hungary
EURATOM (Germany)	Ksenia Aleynikova	10/15/2016 – 10/22/2016	Kyoto, Japan
EURATOM (Germany)	Alessandro Zocco	10/22/2016 – 10/27/2016	Kyoto, Japan
EURATOM (Germany)	Axel Könies	10/21/2016 – 10/27/2016	Kyoto, Japan
EURATOM (Germany)	Sergey Bozhenkov	10/24/2016 – 10/28/2016	Toki, Japan
EURATOM (Germany)	Joachim Geiger	10/02/2016 – 10/29/2016	Toki, Japan
EURATOM (Germany)	Pavel Aleynikov	10/15/2016 – 10/29/2016	Kyoto, Japan
EURATOM (Germany)	Joaquim Loizu	03/06/2016 – 03/11/2016	Madrid, Spain
EURATOM (Germany)	Jens Knauer	11/12/2016 – 11/26/2016	Toki, Japan
EURATOM (Germany)	Per Helander	01/16/2016 – 03/12/2016	Oxford, UK
EURATOM (Germany)	Josefine Proll	07/10/2016 – 07/12/2016	Eindhoven, Netherlands
EURATOM (Germany)	Josefine Proll	07/24/2016 – 08/12/2016	Toki, Japan
EURATOM (Germany)	Pavel Aleynikov	07/19/2016 – 08/12/2016	Princeton/Austin,/San Diego, USA
EURATOM (Italy)	Fabio Pisano	10/04/2016 – 11/04/2016	Greifswald, Germany
EURATOM (Italy)	Andrea Tancetti	09/26/2016 – 05/31/2017	Greifswald, Germany
EURATOM (Netherlands)	Niek Lopez Cardozo	02/28/2016 – 02/29/2016	Greifswald, Germany
EURATOM (Netherlands)	Leo Maas	04/07/2016 – 04/08/2016	Greifswald, Germany
EURATOM (Poland)	Monika Kubkowska	01/11/2016 – 01/15/2016	Greifswald, Germany

Contracting Party	Name	Dates	Location
EURATOM (Poland)	Slawomir Jablonski	01/11/2016 – 01/15/2016	Greifswald, Germany
EURATOM (Poland)	Jarec Kacarczyk	01/11/2016 – 01/22/2016	Greifswald, Germany
EURATOM (Poland)	Agata Czarnecka	01/17/2016 – 01/30/2016	Greifswald, Germany
EURATOM (Poland)	Anna Dzikowicka	02/15/2016 – 03/23/2016	Greifswald, Gemrany
EURATOM (Poland)	Natalia Krawczyk	01/11/2016 – 03/24/2016	Greifswald, Germany
EURATOM (Poland)	Tomasz Fornal	01/11/2016 – 03/24/2016	Greifswald, Germany
EURATOM (Poland)	Monika Kubkowska	03/02/2016 – 03/04/2016	Greifswald, Germany
EURATOM (Poland)	Anna Dzikowicka	04/04/2016 – 04/15/2016	Greifswald, Germany
EURATOM (Poland)	Jacek Kacmarczyk	02/24/2016 – 03/05/2016	Greifswald, Germany
EURATOM (Poland)	Slawomir Jablonski	02/25/2016 – 03/05/2016	Greifswald, Germany
EURATOM (Poland)	Anna Dzikowicka	05/11/2016 – 05/25/2016	Greifswald, Germany
EURATOM (Poland)	Ireneusz Ksiazek	01/18/2016 – 02/09/2016	Greifswald, Germany
EURATOM (Poland)	Grzegorz Pelka	11/14/2016 – 12/09/2016	Greifswald, Germany
EURATOM (Poland)	Ryc Leszek	03/02/2016 – 03/11/2016	Greifswald, Germany
EURATOM (Poland)	Agata Czarnecka	02/28/2016 – 03/12/2016	Greifswald, Germany
EURATOM (Portugal)	Bernardo Brotes de Carvalho	02/01/2016 – 02/05/2016	Greifswald, Germany
EURATOM (Spain)	Emilio Blanco	02/01/2016 – 02/06/2016	Greifswald, Germany
EURATOM (Spain)	Hugo Peraza	05/09/2016 – 06/10/2016	Greifswald, Germany
EURATOM (Spain)	Francesco Cordella	10/11/2016 – 10/13/2016	Greifswald, Germany
EURATOM (Spain)	Gerado Claps	10/11/2016 – 10/13/2016	Greifswald, Germany
EURATOM (Spain)	Alena Gogoleva	09/04/2016 – 02/17/2017	Greifswald, Germany
EURATOM (Sweden)	Mathias Hoppe	06/20/2016 – 07/31/2016	Greifswald, Germany
Japan	Hiroshi Kasahara	02/19/2016 – 03/01/2016	Greifswald, Germany
Japan	Ryohsuke Seki	02/19/2016 – 03/01/2016	Greifswald, Germany

Contracting Party	Name	Dates	Location
Japan	Ogawa Kunihiro	02/25/2016 – 03/02/2016	Greifswald, Germany
Japan	Sadayoshi Murakami	05/08/2016 – 05/14/2016	Greifswald, Germany
Japan	Chihiro Suzuki	11/07/2016 – 11/07/2016	Greifswald, Germany
Japan	Byron Peterson	07/13/2016 – 07/15/2016	Greifswald, Germany
Japan	Yasuhiro Suzuki	07/11/2016 – 07/15/2016	Greifswald, Germany
Japan	Naoki Kenmochi	07/18/2016 – 07/22/2016	Greifswald, Germany
Japan	Ryo Yasuhara	07/18/2016 – 07/22/2016	Greifswald, Germany
Japan	Hayato Tsuchiya	01/20/2016 – 03/08/2016	Greifswald, Germany
Japan	Motoko Nakata	09/01/2016 – 09/23/2016	Greifswald, Germany
Japan	Ichihiro Yamada	02/08/2016 – 02/12/2016	Greifswald, Germany
Japan	Ryo Yasuhara	02/08/2016 – 02/12/2016	Greifswald, Germany
Japan	Toru Li Tsujimura	02/08/2016 – 02/12/2016	Greifswald, Germany
Japan	Xianli Huang	11/09/2016 – 02/05/2017	Greifswald, Germany
Russia	Mikhail Mikhailov	02/01/2016 – 03/11/2016	Greifswald, Germany
Russia	Denis Mironov	11/21/2016 – 11/23/2016	Greifswald, Germany
Russia	Mikhail Mikhailov	11/14/2016 – 12/16/2016	Greifswald, Germany
UK	Florian Köchl	04/19/2016 – 04/22/2016	Greifswald, Germany
UK	Brendan Shanahan	04/04/2016 – 04/06/2016	Greifswald, Germany
UK	Bogdan Teaca	10/03/2016 – 10/08/2016	Greifswald, Germany
UK	Sarah Newton	07/03/2016 – 07/09/2016	Greifswald, Germany
UK	Adam Deller	09/21/2016 – 09/23/2016	Greifswald, Germany
UK	Tianbo Wang	09/12/2016 – 09/23/2016	Greifswald, Germany
UK	John Connor	09/11/2016 – 09/25/2016	Greifswald, Germany
UK	Felix Parra	11/13/2016 – 11/26/2016	Greifswald, Germany

Contracting Party	Name	Dates	Location
Ukraine	Vadym Lutsenko	09/04/2016 – 09/16/2016	Greifswald, Germany
Ukraine	Yaroslav Kolesnichenko	09/04/2016 – 09/16/2016	Greifswald, Germany
USA	Florian Effenberg	01/04/2016 – 01/16/2016	Greifswald, Germany
USA	Jeanette Maisano-Brown	06/13/2016 – 09/02/2016	Greifswald, Germany
USA	Jeffrey Harris	01/31/2016 – 02/19/2016	Greifswald, Germany
USA	Mark Cianciosa	02/06/2016 – 02/20/2016	Greifswald, Germany
USA	Samual Lazerson	01/04/2016 – 02/29/2016	Greifswald, Germany
USA	Peter Traverso	01/21/2016 – 04/03/2016	Greifswald, Germany
USA	Sam Lazerson	06/26/2016 – 07/03/2016	Greifswald, Germany
USA	Nerea Panadero Alvarez	09/05/2016 – 12/03/2016	Greifswald, Germany
USA	Novimir Pablant	02/28/2016 – 03/19/2016	Greifswald, Germany
USA	Saskia Mordijck	03/17/2016 – 03/19/2016	Greifswald, Germany
USA	David Gates	03/20/2016 – 03/26/2016	Greifswald, Germany
USA	Laurie Stephey	01/16/2016 – 03/31/2016	Greifswald, Germany
USA	Eric Edlund	04/03/2016 – 04/15/2016	Greifswald, Germany
USA	Jeffrey Harris	05/22/2016 – 05/27/2016	Greifswald, Germany
USA	John Schmitt	05/16/2016 – 05/27/2016	Greifswald, Germany
USA	Novimir Pablant	05/16/2016 – 05/27/2016	Greifswald, Germany
USA	Samuel Lazerson	05/16/2016 – 05/27/2016	Greifswald, Germany
USA	Samuel Lazerson	05/15/2016 – 05/28/2016	Greifswald, Germany
USA	James Terry	05/22/2016 – 05/29/2016	Greifswald, Germany
USA	Novimir Pablant	01/10/2016 – 02/06/2016	Greifswald, Germany
USA	Jeanette Maisano-Brown	06/12/2016 – 06/18/2016	Greifswald, Germany
USA	Harold Weitzner	06/01/2016 – 06/30/2016	Greifswald, Germany

Contracting Party	Name	Dates	Location
USA	Victoria Winters	07/10/2016 – 07/23/2016	Greifswald, Germany
USA	Florian Effenberg	05/22/2016 – 07/30/2016	Greifswald, Germany
USA	Matthew Stoneking	07/03/2016 – 07/08/2016	Greifswald, Germany
USA	Matthew Stoneking	08/06/2016 – 08/16/2016	Garching, Germany
USA	James Danielson	08/08/2016 – 08/18/2016	Garching, Germany
USA	Glen Wurden	08/16/2016 – 09/09/2016	Greifswald, Germany
USA	Eric Edlund	05/22/2016 – 06/10/2016	Greifswald, Germany
USA	Florian Effenberg	03/07/2016 – 03/11/2016	Greifswald, Germany
USA	Oliver Schmitz	03/07/2016 – 03/11/2016	Greifswald, Germany
USA	Glen Wurden	01/19/2016 – 02/12/2016	Greifswald, Germany
USA	John Schmitt	09/11/2016 – 10/12/2016	Greifswald, Germany
USA	James Danielson	12/08/2016 – 12/18/2016	Garching, Germany
USA	Matthew Stoneking	12/08/2016 – 12/18/2016	Garching Germany
USA	Glen Wurden	11/14/2016 – 11/13/2017	Greifswald, Germany

6.10 List of journal articles

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