Technology Collaboration Programme on the Stellarator-Heliotron Concept

(SH-TCP)

Annual Report 2018

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1 Preface

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" (ISHW) serves as a 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).

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 $\sim$ 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.

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	EU	L.-G Eriksson	European Commission
	Germany	R. Wolf (Chair) T. Klinger (alternate)	Max-Planck-Institute for Plasma Physics
	Spain	J. Sanchez (alternate)	CIEMAT
NIFS	Japan	Y. Takeiri (Vice Chair)	National Institute for Fusion Science
		T. Morisaki	National Institute for Fusion Science
ROSATOM	Russia	B. Kuteev A. Melnikov (alternate)	National Research Center, Kurchatov Institute
		V. Ivanov S. V. Shchepetov (alternate)	Prokhorov General Physics Institute of Russian Academy of Sciences
NSC	Ukraine	I.E. Garkusha V. Moiseenko (alternate)	Institute of Plasma Physics, National Science Center "Kharkov Institute of Physics and Technology"
		V.S. Voitsenya D. Grekov (alternate)	Institute of Plasma Physics, National Science Center "Kharkov Institute of Physics and Technology"
US DOE	USA	D.T. Anderson	Wisconsin University
		D. Gates	Princeton Plasma Physics Laboratory
Observers		C. Hidalgo	CIEMAT
		S. Kubo	National Institute for Fusion Science
		I. Vargas Blanco J. Moira	Costa Rica Institute of Technology
		Y. Xu	Southwest Jiatong University
		M. Yokoyama	National Institute for Fusion Science
		P. Kurz (Secretary)	Max-Planck-Institute for Plasma Physics

3.2 Countries targeted to join

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.

4 Meetings

4.1 International Stellarator-Heliotron Workshop (ISHW)

The 22nd International Stellarator Workshop will be held on Sep. 23-27, 2019 in Madison, Wisconsin. An international program committee has been formed (Chair: T.S. Pedersen).

4.2 Coordinated Working Group Meetings (CWGM)

4.2.1 17th Coordinated Working Group Meeting (CWGM)

The 17th Coordinated Working Group Meeting (CWGM17) was held, with about 40 participants, on 6 October 2017 in Kyoto, at the occasion of the 21st International Stellarator-Heliotron Workshop (ISHW). Due to the time constraint after the adjournement of the ISHW (~2 hours), the main purpose of this meeting was the follow-up of the previous 16th CWGM (cf., Stellarator News, Issue 158, August 2017).

The agenda was as follows:

- Brief report from 16th CWGM (Jose-Luis Velasco)
- EUROfusion supported activities in NIFS (Andreas Dinklage, on behalf of Arturo Alonso)
- Discussion on a couple of sessions with ON-GOING intensive collaborations:
    - Transport modelling (Shinsuke Satake)
    - Energetic particles/AEs control (Satoshi Yamamoto)
    - Impurity transport (mainly on TESPEL injection) (Naoki Tamura)
    - Core Electron-root Confinement (Felix Warmer)
    - Turbulence/isotope effect (Motoki Nakata)
- Setting up milestones: joint actions, joint papers etc.

The materials presented in this meeting are available at http://ishcdb.nifs.ac.jp/ and http://fusionsites.ciemat.es/cwgm17/ for those of you having further interests.

Strengthening links to ITPA, and then ITER was raised in the discussion. Since there were several ITPA members among the participants of this CWGM, recent activities and updates in each ITPA topical group (energetic particles, transport and confinement, edge and pedestal, and, integrated operation scenario) were briefly introduced. Also, replacement of "Stellarator Representative" to ITPA topical group was negotiated in the Executive Committee Meeting of IEA TCP-SH. Once it is authorized, it would be a good idea to show introduce the list of Stellarator Representatives in Stellarator News, for facilitating strategic discussions between CWGM and ITPA.

4.2.2 18th Coordinated Working Group Meeting (CWGM)

The 18th CWGM was held in Princeton, NJ USA on from April 10th-12th 2018. There were a total of 59 presentations from 45 from onsite participants, and 14 from offsite participants. Representatives from 14 institutions and 9 countries gave presentations.

Talks covered a wide range of topics:

- Divertor physics; W7-X scraper elements (section leader: Oliver Schmitz)
- 3D Turbulence; isotope effect (section leader: Moto Nakata)
- Database Progress and ITPA Links (section leader: Jose Luis Velasco)
- Impurity Transport (section leader: Novimir Pablant)
- Core Electron Root Confinement (section leader: Felix Warmer)

- Plasma Terminating Events by Excess Fuelling and Impurities (section leader: Andreas Dinklage)
- Wall Conditioning (section leader: Paco Tabares)
- Fuelling and Pellet Injection (section leader: Naoki Tamura)

Numerous joint activities were identified and responsible individual were identified. The meeting was widely attended and many good discussions resulted. The presentations are available at the meeting website located at: https://sites.google.com/a/pppl.gov/cwgm18/ .

Figure 1: Group photo from the 18th CWGM

4.3 Executive Committee (ExCo) meetings

The 47th Executive Committee took place on October 24, 2018 in Ahmedabad, India. The ExCo nominated Alvaro Cappa to replace Axel Könies in the ITPA Energetic Particle Physics Topical Group, confirmed the International Programme Committee for the ISHW 2019 in Madison discussed and decided on a structure for future CWGM reporting milestones and received progress reports from the CWGM and the SSOCG. The ExCo also received briefings about the member's domestic stellarator activities. I. Vargas supplied an update on the progress of the accession of Costa Rica and Y. Xu gave a presentation on the Chinese stellarator activities.

5 Activities and Outcomes

5.1 Heating and fuelling

5.1.1 Pellet Injector for Heliotron J (Kyoto U / NIFS)

A pellet injector was developed for Heliotron J in collaboration with NIFS. The injector was successfully applied to the Heliotron J device, and the stored energy of 5.4 kJ was achieved as well as high-intense gas puffing method.

5.1.2 Pellet physics and modelling (CIEMAT / NIFS / IPP-Greifswald / ORNL)

It was determined that pellet fuelling efficiency in TJ-II can range from about 20% to 80%, this value depending strongly on the pellet penetration depth. With the expansion of the TJ-II pellet database it has been observed that pellet fuelling efficiency can benefit from the presence of a population of fast electrons in its plasma core. Simulations of post-injection electron density profiles made with the TJ-II HPI2 code are in good agreement with Thomson Scattering density profiles. However, there are significant discrepancies between the simulated and experimental density profiles for scenarios with fast-electron effects.

Recently, a TESPEL injector was temporarily implemented onto the up-stream end of pellet injector thereby making it a unique system as both pellet types can be injected along adjoining guide tubes into the same toroidal sector of TJ-II, albeit not simultaneously.

5.1.3 First measurements of density fluctuations in both positive and negative density gradient regions of the plasma (CIEMAT / Kurchatov Institute-Moscow / NSC KIPT-Kharkov)

First 2-D poloidal contour plots of plasma potential and density fluctuations have been measured with the TJ-II HIBP diagnostic, which have allowed to characterise turbulence in positive and negative gradient regions: density fluctuations appear both at the positive and negative gradient regions, their amplitude being minimum in the zero density gradient zone while it is stronger in the negative than in the positive gradient region. Gyrokinetic simulations performed with EUTERPE for ECRH plasmas yield results consistent with the experiment.

5.2 Confinement: anomalous transport/turbulence, neoclassical transport, isotope effect, impurity transport

5.2.1 Impurity Transport in W7-X (NIFS / IPP)

The impurity transport of the W7-X plasmas has been investigated by using a core (TESPEL) and edge (LBO) impurity sources. The symptom of the accumulation of impurity injected by the TESPEL was observed in the high-density plasma with a low-heating power.

5.2.2 Fast Ion Loss Detector (NIFS / IPP)

A Faraday-cup-based fast ion loss detector (F-FILD) optimized for W7-X was developed in NIFS and was installed in W7-X. Escaping beam ions were successfully measured with the F-FILD in W7-X.

Poster presentation by K. Ogawa (NIFS) et al., based on NIFS-IPP collaboration. “Development of Faraday-cup-based Fast Ion Loss Detector in Wendelstein 7-X”, The 45th EPS conference on Plasma Physics, Prague, Czech Republic, Jul. 2-6 (P5.1001).

5.2.3 X-ray Imaging Spectroscopy on W7-X (PPPL / Auburn / IPP)

Dr. Novimir Pablant (PPPL) operated the XICS diagnostic providing radial electric field measurements and ion temperature profiles. Peter Traverso (Auburn University) provided analysis of Argon impurity transport data. Dr. David Ennis (Auburn University) measured counter-streaming plasma flow in the island divertor on W7-X

5.2.4 Gyrokinetic simulations with GKV for LHD experiments (PPPL/NIFS/IPP

Gyrokinetic simulation studies using GKV and the associated LHD experiments have made a progress in understanding of the isotope effects on turbulent transport and zonal flow generation. Also, the preparative benchmark activity between GKV and GENE has been conducted in collaboration, and the isotope and impurity effects in W7-X will be addressed.

5.2.5 Stellarator impurity flux driven by electric fields tangent to magnetic surfaces (CIEMAT / University of Oxford / NIFS)

Analytical calculation of the neoclassical radial impurity flux, incorporating the effect of the component of the electric field that is tangent to the magnetic surface such effect has been investigated, showing that it can be very strong for highly charged impurities. Once it is taken into account, the dependence of the impurity flux on the radial electric field reappears.

5.2.6 Electrostatic potential variation on the flux surface and its impact on impurity transport (CIEMAT / IPP / NIFS)

We have considered different stellarator configurations (LHD, W7-X, TJ-II) and assessed the impact that *potential variation on the* flux surface has on the radial particle transport of selected impurities. Experimental validation with TJ-II Doppler Reflectometry (DR) of the variation of the radial electric field on the flux surface in electron-root stellarator plasmas has been started, showing that experimental results are quantitatively captured by the numerical simulations.

5.2.7 Heat Transport studies: (CIEMAT / IPP-Greifswald / JET)

The investigation of the radial propagation of small, spontaneously generated, temperature perturbations using Transfer Entropy has been carried in stellarators (TJ-II, W7-X) and tokamaks (JET). We show that heat transport in TJ-II is not a smooth and continuous (diffusive) process, but involves mini-transport barriers associated with low-order rational surfaces and rapid non-local radial 'jumps'. In addition, we find that the non-local contribution to transport becomes more prominent at higher input power

5.3 Stability and equilibrium: high-beta operation, stability limits

5.3.1 Parametric Equilibrium Reconstructions for W7-X (Auburn / PPPL / IPP)

John Schmitt (Auburn University) provided equilibrium reconstructions using the V3FIT code.

5.3.2 *Control of fast particle driven MHD modes:* (Kyoto U / NIFS / CIEMAT / Kurchatov Institute / IPP)

Energetic-particle-driven MHD instabilities were studied on LHD, Heliotron J and TJ-II. The global Alfven eigenmodes and energetic modes were stabilized or mitigated with ECH/ECCD.

Recent experiments have been carried out in TJ–II NBI plasmas using ECRH on-axis with and without ECCD, in order to study the influence of Electron Cyclotron Current Drive (ECCD) on the observed Alfv́en Eigenmodes (AEs). The result indicates that the experimentally observed steady frequency mode could correspond to modes appearing in the HAE2,1 gap. This gap becomes wider as the iota profile evolves from the pure NBI to the NBI+ECCD case, thus favouring the presence of the mode in the latter case.

5.3.3 MHD equilibrium: (CIEMAT / EPFL / IPP-Greifswald)

Theoretical studies on the MHD equilibrium of a four-fold advanced helical device [47] have demonstrated that the energy of periodicity-breaking perturbed configurations can be found in local minima with respect to the perturbation parameter. These minima lie below the energy of the unperturbed configurations and provide a natural explanation for the ease with which periodicity-breaking MHD modes can be found in real experiments.

5.3.4 Role of isotope mass and evidence of fluctuating zonal flows during the L-H transition (CIEMAT / SWIPT / NIFS)

Mean radial electric fields as well as low frequency Zonal Flow-like global oscillations in radial electric field have been identified during the low to high (L–H) transition in Hydrogen and Deuterium dominated plasmas in the stellarator TJ-II. No evidence of isotope effect on the L–H transition dynamics was observed in the investigated TJ-II plasma scenarios. These observations emphasize the critical role of both zero frequency (equilibrium) and low frequency varying large-scale flows for stabilizing turbulence during the triggering of the L–H transition. Furthermore, TJ-II results show how sensitive are the properties of zonal flows to ECRH and NBI plasma conditions, providing a key experimental guide for model validation.

5.4 Heat and particle exhaust and plasma wall interaction

5.4.1 Infrared Cameras on W7-X (LANL / IPP)

Glen Wurden (LANL) provided calibrated infrared camera images of the W7-X divertor.

5.4.2 Gas Puff Imaging (MIT / IPP)

MIT's collaboration with W7-X on Gas-Puff-Imaging operated a fast-framing camera with a view of the W7X cross-section during all of OP 1.2. This fast-camera work has contributed to the study of fluctuations and plasma structure in the plasma edge and in the island-divertor regions. Four different MIT staff have been involved with this task.

5.4.3 W7-X TDU scraper elements (ORNL/IPP)

Jeremy Lore organized and ran experiments investigating the TDU scraper element on W7-X.

5.4.4 Powder Injector on W7-X (PPPL/IPP)

Dr. Robert Lunsford (PPPL) installed the Probe Mounted Powder Injector (PMPI) on W7-X and ran experiments examining the effect of boron powder injection on plasma performance.

5.4.5 W7-X TDU heat flux assymetries (PPPL/IPP)

Dr. Samuel Lazerson measured the impact of error fields on divertor heat flux asymmetries on W7-X

5.4.6 Thermal Helium beam for W7-X plasma edge (UW Madison / IPP)

A thermal helium beam for measurement of edge electron density and temperature profiles has been commissioned at W7-X by UW Madison researcher Dr. Tullio Barbui and PhD student Erik Flom. The diagnostic has been used to characterize the plasma edge conditions during the first island divertor campaign. EMC3-EIRENE modelling has continued to study radiative edge cooling and according experiments have been performed by UW Madison researcher Dr. F. Effenberg, who graduated as PhD on this topic in 07/18. He delivered an IAEA oral talk on the topic.

5.4.7 Wisconsin In-Situ Penning Gauges (UW Madison / IPP)

A set of in-situ Penning gauges (Wisconsin In-Situ Penning, WISP) has been installed and commissioned at W7-X by UW Madison PhD student T. Kremeyer. First measurements of hydrogen and helium neutral gas compression in the island divertor were made in a dedicated experiment planned and executed by T. Kremeyer.

5.4.8 W7-X TDU erosion investigations (UW Madison / ORNL / IPP)

The erosion source from the island divertor baffle and target areas at W7-X was measured by spectroscopic means by UW Madison PhD student V. Winters utilizing the Oak Ridge Filter Scope system. An according experiment was planned and executed by V. Winters.

5.4.9 PWI and Color analysis of W7-X PFCs (NIFS / IPP)

In-situ color analysis of plasma facing surfaces in W7-X vacuum vessel was conducted after OP1.2a. The analysis will be conducted again after OP1.2b in January 2019.

The colorimetry measurements conducted in W7-X can provide the wide-range of distribution of the deposition layer, which bridges the gap of the results between in the post-mortem analysis and in global particle balance analysis. These colorimetry measurements will contribute to fuel retention study of the first wall in W7-X.

Some first wall protection tiles made of graphite in W7-X were sent to NIFS for PWI analyses

5.4.10 LHD Divertor studies (NIFS / UW Madison)

Finite beta effects on heat and particle fluxes collaborative experiment on finite beta effects on heat and particle flux profiles on LHD divertor was conducted. Langmuir probe and IR camera data were obtained, and they are under analyses.

Aaron Bader (UW-Madison) provided analysis of the LHD divertor.

5.4.11 Impact of the radial electric fields on turbulence spreading in the edge and Scrape-Off Layer (CIEMAT / IPP- / NIFS / Consorzio RFX)

Experiments in the TJ-II stellarator have shown that when Er × B sheared flows achieve gradients comparable to the inverse of the turbulence correlation time, they affect the level of turbulence spreading and edge-SOL coupling. Hence, the shearing rate of edge radial electric fields can be an important tool to suppress turbulence and decouple edge and SOL regions.

5.4.12 Neutral dynamics and turbulence in TJ-II (CIEMAT)

The impact of neutral fluctuations on the observed turbulent structures has been investigated in TJ-II, showing that thermal neutrals react to low frequency plasma fluctuations, becoming also turbulent. Hence, neutral-induced non-linearities would be expected in plasma turbulence. A triple boundle technique has been developed to investigate density, electron temperature and neutral dynamics.

5.4.13 Plasma facing components based on liquid metals (CIEMAT)

Two liquid metals (LM), Li and LiSn, presently considered as alternative materials for the divertor target of a fusion reactor, have been exposed to the plasma in a capillary porous system (CPS) arrangement in TJ-II [65]. A negligible perturbation of the plasma has been recorded in both cases, even when stellarator plasmas are particularly sensitive to high Z elements due to the tendency to central impurity accumulation. With respect to the potential use of LiSn alloys as LM for an alternative target in DEMO, the results obtained in TJ-II agree with the expectations from laboratory results, namely a dominant Li emission from the alloy when exposed to the plasma, in spite of its minority in its composition.

5.5 Other topics

5.5.1 US collaboration with W7-X

A group of US scientists collaborating with W7-X have re-instituted regular video-conferences with members of the W7-X CoDaC team with the mission of facilitating easier remote collaboration and data access at W7-X. At present the US participants include Novimir Pablant (PPPL), Sean Ballinger (MIT), and Jim Terry (MIT – US organizer).

Japan:

5.5.2 Multi-Channel Radiometer System for Heliotron J

A multi-channel radiometer system for electron temperature fluctuation was developed in Heliotron J in collaboration with IPP, Greifswald.

5.5.3 Triton-burn-up measurements on LHD (NIFS / IPP)

In LHD, NIFS-IPP Greifswald joint experiments on triton burnup and effect of RMP field on beam ion confinement were conducted.

5.5.4 Slow phase drifts on CO_2 laser interferometer (NIFS / General Atomics / IPP)

A CO_2 laser interferometer including a dispersion interferometer, which is installed on W7-X, LHD, and DIII-D, has a problem of slow phase drifts. This causes measurement errors in steady-state discharges. The reason had not been clarified for long time. In 2018, German (IPP-Greifswald), Japan (NIFS), and US (GA) researchers discussed about this issue with their experiences and experiment data and confirmed that the humidity caused the drifts. This is a quite important accomplishment for the electron density measurement in steady-state discharge on not only W7-X but also ITER. This result has been published in the collaboration paper (Brunner, K.J. et. al., Journal of Instrumentation 2018).

6 Summary Domestic Reports and Device Status

6.1 Australia

As foreshadowed, with the transfer of H-1 to China, stellarator research on-site at ANU is mainly theoretical including Prof. Matthew Hole in the Mathematical Sciences Institute plus a fraction of a post-doc, several PhD students and two emeritus staff.

H1 Relocation: The exchange agreement between ANU and USC was finalised and signed early this year. Bids for the MAGPIE components supplied by China are in progress. ANU (and IPP) is assisting with MHD and RF computation and assessment of RF and transport bids.

Simons Foundation Grant: Em. Prof. Dewar leads the ANU participation in the multi-party international "Simons Collaboration on Hidden Symmetries and Fusion Energy Research" grant, with a main goal being stellarator optimisation. The ANU team including co-investigator A/Prof Hole and Dr. Qu will host collaborators under this grant, and will be focussing on MHD equilibrium and stability over the four year duration.

Coherence Imaging: Beautiful flow images for several island chains were obtained by the W7-X imaging group using Prof. Howard's coherence imaging technique.

An Australian team (led by Prof Howard) from the ANU and the Australian Nuclear Science and Technology Organisation is working with the ITER Organisation to prepare such a coherence imaging system for scrape-off-layer and divertor imaging of impurity flows and temperatures. Preparations are underway for formal Conceptual Design Review in March 2019.

Collaborations are active with Germany, Japan and the USA.

6.2 European Union

6.2.1 Germany

Wendelstein 7-X campaign OP 1.2b

The last operating campaign, which ended in October 2018, represented the last campaign with inertially cooled Divertor. The main objectives of the campaign were to develop stationary discharge scenarios in high-density hydrogen plasmas while controlling the thermal loads on the divertors. More than 300 experiment proposals were carried out with a total of 20 national and international partners. For the first time improved wall conditioning by boronization was performed in W7-X. As a result, the greatly reduced concentration of impurities in the plasma (up to 10-fold) made it possible for the first time to routinely operate hydrogen plasmas with densities of $1{\cdot}10^{20}\mathrm{m}^{-3}$ [1]. These high-density plasmas were heated by electron cyclotron resonance heating (ECRH), where the polarization was dynamically varied from X2 to O2 during the discharge. With these high plasma densities, it was possible to perform scenarios where the thermal loads on the divertors were moderate due to detachment and remained far below the maximum permissible temperature even for the cooled divertor, which is to be installed during the next completion phase. This made it possible to increase the maximum heating energy from initially 80 MJ to 200 MJ and to achieve stationary hydrogen discharges with a duration of 30s. With reduced heating power, the discharge length could even be increased to 100s. Decisive for the divertor operation is the control of the position of the increased heat loads of the strikelines due to the temporally developing toroidal bootstrap current. On the one hand this effect could be counteracted by dynamic adaptation of the rotational transformation by the main field coils, on the other hand it was possible to very quickly impose the asymptotic value of the bootstrap current by means of active current drive using the ECRH and thus to keep the position of the heat loads almost constant over the discharge period. In preparation for operation with high plasma and correspondingly high toroidal currents, shielding plates (scraper elements) were qualified to mitigate increased thermal loads on the edges of the divertor. Two of these plates were successfully operated and the divertor edge protection was successful. As an additional heating system, the neutral injection heating with a maximum output of 3.5 MW was used for the first time on W7-X. The heating system was neutral injection heating with a maximum output of 3.5 MW. It was possible to maintain the plasma discharge by this heating method alone. Due to the introduction of neutral particles, the highest plasma density of $2{\cdot}10^{20}m^{-3}$ observed to date at Wendelstein 7-X was achieved. Numerous indications have been observed that support an improvement of neoclassical transport in W7-X. Measurements of the radial electric field as a parameter for neoclassical transport processes show good agreement with theoretical predictions. However, in general another strong transport channel has been identified. This is particularly reflected in the inclusion behaviour of actively introduced impurities, which do not accumulate centrally but show a strong anomalous diffusion. This suggests that turbulence plays a major role in the regulation of radial losses of particles and energy. Particularly in discharges that are centrally refilled with neutral gas and develop centrally elevated density profiles, an extension of the inclusion time of the impurities with simultaneous reduction of the turbulence level in the plasma is observed. This effect is particularly pronounced in pellet shot discharges where the maximum plasma energies could be reached up to 1.2MJ with simultaneous equilibration of electron and ion temperature T_e=T_i=3keV. First results suggest that this is a special property of the W7-X magnetic field geometry which makes the growth of instabilities based on trapped electrons more difficult.

[1] *T. Klinger, T. Andreeva, S. A Bozhenkov, C. Brandt, R. Burhenn, B. Buttenschön, G. Fuchert, B. Geiger, O. Grulke, H. P. Laqua, N. A. Pablant, K. Rahbarnia, T. Stange, A. v. Stechow, N. Tamura, H. Thomsen, T. Wegner, R. Bussiahn: Overview of first Wendelstein 7-X high-performance operation. Nuclear Fusion, in press,* doi: 10.1088/1741-4326/ab03a7

6.2.2 **Spain**

TJ-II stellarator. The most important topics investigated in the TJ-II stellarator in the last two years are the following: 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.

As regards impurity transport research, a number of working lines exploring several recently discovered effects have been developed: the effect of tangential drifts on stellarator neoclassical transport, the impurity flux driven by electric fields tangent to magnetic surfaces and attempts of experimental validation with Doppler reflectometry of the variation of the radial electric field on the flux surface.

Concerning gyrokinetic simulations, two validation activities have been performed, the comparison with measurements of zonal flow relaxation in pellet-induced fast transients and the validation of the simulated localization of instabilities with density fluctuations spectra measured by Doppler reflectometry.

The impact of radial electric fields on turbulence spreading in the edge and Scrape-Off Layer has been experimentally characterized using a 2-D Langmuir probe array. Another remarkable piece of work has been the investigation of the radial propagation of small temperature perturbations using Transfer Entropy.

Research on the physics and modelling of plasma core fuelling with pellet and TESPEL injection has produced also relevant results. NBI-driven Alfvénic activity and its possible control by ECCD has been examined as well in TJ-II.

Finally, alternative plasma facing components based on liquid metals are under investigation.

6.3 Japan

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); 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 were 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.

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.

The joint development on fast Thomson scattering system has been conducted through the collaboration between NIFS and University of Wisconsin-Madison. The power supply for the system will delivered by December 2018 from US to NIFS, and it will begin operation within 20th campaign.

As for Heliotron J (Kyoto University), 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 configuration effect on confinement and transport, high-density H-mode produced by high intense gas puffing and pellet injection, electron internal transport barrier (eITB), response of a core coherent density oscillation on ECH, toroidal and poloidal rotation, production of NBI plasmas with 2.45GHz non-resonant microwaves, isotope effect on plasma turbulence, stabilization of energetic particle driven MHD instabilities by ECH/ECCD, confinement of high energetic particles produced by ICRF, impurity transport and edge plasma. The CXS (Charge exchange spectroscopy) system has been upgraded to deliver more accurate measurement data of the toroidal flow.

6.4 Russia

6.4.1 1. Observation of electromagnetic mode in theoretically ideally MHD stable L-2M stellarator plasmas

MHD (magnetohydrodynamic) plasma equilibrium and stability in configuration of L-2M stellarator have been studied extensively by the use of direct numerical and asymptotic methods. The vacuum magnetic configuration has a magnetic hill; however, due to the effect of plasma self-stabilization, a magnetic well appears in the center of the plasma column. Under our experimental conditions, ideal internal MHD modes are stable in the central part of plasma due to magnetic well, and due to magnetic shear at the plasma edge. Numerical simulations showed that large-scale ideal internal MHD modes are stable. It was also shown there that ideal ballooning modes were stable in all equilibrium configurations under study, including those in which the plasma pressure exceeded the maximum experimental value manifold. However, external ideal peeling modes having threshold with respect to the plasma pressure gradient are found to be unstable. If peeling mode is stable, an electromagnetic mode having thresholds in the plasma density and pressure was observed. The characteristic frequency of the unstable mode was 70–90 kHz, and the direction of its rotation pointed towards the direction of ion diamagnetic drift. The instability was observed at $n(0) > 1.5 \times 10^{13}$ cm^{-3} and $\langle\beta\rangle > 0.14\%$, where $n(0)$ is the plasma density averaged over the central chord and $\langle\beta\rangle$ is volume-averaged ratio of the gas kinetic pressure to the magnetic pressure. This phenomenon cannot be described within the theory of resistive interchange modes. Analytical estimations in the framework of two fluid magnetohydrodynamics were performed. Calculations and experimental data are in reasonable agreement.

6.4.2 2. Second harmonic ECRH breakdown: a theoretical insight and comparison to experimental results from L-2M

The 2nd harmonic electron cyclotron heating (ECRH) breakdown in stellarator was studied theoretically. The collisionless time-averaged electron dynamics in a microwave field at a frequency close to the 2nd ECR harmonic was re-examined for the magnetic field typical to stellarators. Specifically, we intended to make theoretical estimations that may be compared with the experimental results from the L-2M stellarator. Under the experimental conditions, at neutral densities $\sim 10^{13}$ cm^{-3} the mean free path of electron is much less than the magnetic axis length. Therefore, when studying the collisionless dynamics, the magnetic modulation along the field lines was approximated by a sinusoid with two varying parameters. The equations have been treated numerically and analytically. Our analysis has shown that there exist four groups of electrons, which strongly differ in the amplitude of energy excursions, and that all of them are of practical interest for the breakdown. The boundaries of these groups in the 2D parametric space have been determined. It was shown that in L-2M the electrons that undergo the most intense energy oscillation (the group of nonlinear regime) are concentrated in the close vicinity of magnetic axis. However, this group may be useful for the breakdown only at very low ECR detuning magnitudes near the axis, while the breakdown efficiency observed in experiments is by far less sensitive. On the whole, other groups of electrons are responsible for the breakdown. One of them is also capable of creating the electron avalanche near the magnetic axis, and it is found to be quite robust to the variation of magnetic field. Simultaneously and at almost the same rate, the electrons of this group produce excited species of neutrals, which later on can be ionized in collisions with electrons of significantly subthreshold energy. The excited neutrals then freely travel across the magnetic field and become ionized by the collisions with electrons or by ultraviolet radiation. In this way the breakdown is expanded across the magnetic surfaces, and its rate depends mainly on the average kinetic energy of neutrals. We have suggested quite a simple analytical estimate for the breakdown delay time, which seems to be in a good agreement with the L-2M experimental results.

The model that is used in this work is rather adaptive and can be updated to describe (pre)ionization in fusion devices. However final estimates may differ depending on both the geometry of the vacuum vessel and the magnetic configuration.

6.5 Ukraine

6.5.1 The movable limiter made of B_4C is installed at Uragan-3M.

For the recent Uragan-2M campaign, a new variant of the movable B_4C-limiter has been designed, manufactured and installed. The influence of the limiter position relative to the minor axis was investigated on plasma parameters in the regime of plasma heating in pulsed RF discharge. The CIII line intensity essentially decreases and OV line increases under limiter positioning at the distance of 15 cm from the wall. The soft X-ray signals appreciably increase at the same time. This can be explained by input of sputtered boron carbide into plasma or increase of plasma temperature.

6.5.2 Plasma fluctuations in visible light emission were provided from two directions

An appearance of various 1-20 kHz oscillations was observed in Uragan-2M. Two multichannel pinhole cameras were recently installed in U-2M for monitoring the oscillations of visible light emission from two positions in the same plasma cross-section. New electronics was designed and manufactured for measuring the plasma density, electron temperature and plasma potential profiles with high time resolution in cold, low density RF conditioning discharges via triple Langmuir probe technique.

6.5.3 New Three-Half-Turn (THT) antennas are in use at Uragan-3M and Uragan-2M.

Three-Half-Turn (THT) antennas that have 3 phi-phased straps oriented perpendicular to the magnetic field lines are used for plasma heating in Uragan-3M and Uragan-2M. It is found in experiments that THT antennas are capable of creating dense plasma at slightly decreased compared to regular regime magnetic fields, but with long idle time. Such feature is investigated at both experimental devices.

6.5.4 The thermal desorption probe was used for *in situ* control of wall conditioning in U-2M

The thermal desorption method has been developed for diagnosing impurity level on Uragan-2M vacuum chamber surfaces *in situ*. Using this method the investigations of outgassing rate were carried out and estimation of the number of molecules layers was done in the Uragan-2M torsatron after wall conditioning by RF plasma discharge in different regimes combined with pumping. With this method the influence of plasma treatment on hydrogen retention and release from 12X18H10T stainless steel (SS) flat was examined under different plasma conditions. The contributions of RF pulsed discharges during wall cleaning and RF pulsed plasma heating regime to hydrogen release were evaluated in Uragan-2M.

6.5.5 First results with witness-probes exposed in Uragan-2M were obtained

The analysis of surface of witness-probes (made of SS) exposed during 2015-2016 experimental campaigns in Uragan-2M vacuum chamber showed that wall conditioning procedures used for that period of time have not provided homogeneous cleaning of vacuum chamber walls.

6.5.6 Modeling of RF plasma production in ICR and ECR frequency ranges

A numerical model of RF plasma production in stellarators in the ion cyclotron and electron-cyclotron frequency ranges is developed. This model is aimed for numerical analysis of the plasma discharge for the vacuum chamber wall conditioning. New features of the model presented are account of molecular ions, H_2^+ and H_3^+, in the particle balance equations. The radio-frequency module of the code is modified accordingly. A new module that calculates second harmonic electron cyclotron heating in case of weak wave damping is created and incorporated into the code.

6.5.7 Re-assembly of the Uragan-2M

Other developments including Uragan-2M refurbishment had been made. The refurbishment comprised full disassembling of the device and cleaning of all the inner walls. The plasma discharges are obtained after assembling of the device. In frame of the refurbishment, the part of the electronics of the power supply for Uragan-2M magnetic field coils is substituted by a new one.

6.5.8 The concept of the stellarator-mirror hybrid plasma device

Theoretical activity (neutron computations) and preparations to experiments in support of the fusion-fission hybrid concept are continued. The concept is based on the stellarator-mirror hybrid plasma device. Such a device has an embedded magnetic mirror having lower magnetic field. The magnetic mirror appears in Uragan-2M when one of the coils of toroidal magnetic field is switched off. This work is carried on within IAEA Collaborative Research Project F13018 “Development of Steady-State Compact Fusion Neutron Sources”. Theoretical part of this study is being performed in collaboration with Uppsala University, Sweden.

6.5.9 International activity

The heavy ion beam probe diagnostics group participated in TJ-II experiments. This activity is both bilateral and within EUROfusion.

Three EUROfusion projects for Wendelstein7-X are approved and now are ongoing. They relate to the localized eigenmode observation and electron cyclotron wall conditioning.

Under EUROfusion umbrella, the collaboration with Belgian LPP-RMA wall conditioning group is developing both in theoretical (TOMATOR-1D plasma start-up tokamak code and a stellarator code) and experimental directions. The joint experiment on neutron particle detection with time-of-flight NPA was organized and run by KTH (Stockholm) plasma team.

The prospects of stellarator research at IPP KIPT are strongly determined by integration of the studies to the Eurofusion Consortium activity within S1 work package.

6.5.10 **Draft plan of works at IPP KIPT during year 2019**

The antenna topologically similar to W7-X ICRH antenna manufactured and installed in Uragan-2M. The tasks of this mock-up are:

- To develop scenarios for wall conditioning for W7-X;
- To develop plasma start-up scenario for W7-X;

6.5.11 **Other works:**

- Further developing of the thermo-desorption diagnostics that provides information on wall conditions in the device.
- Further development and usage of plasma start-up numerical model for U-2M and W7-X start-up and wall conditioning scenarios (in collaboration with LPP-Brussels).
- Manufacturing and installation of wider movable limiter that decreases size of the scrape-off layer and can withstand longer plasma pulses.
- Manufacturing and installation of a new highly efficient cryo-pump that could substantially increase pumping speed.
- Repairing and putting to operation the gettering pump.
- Continue refurbishment of Uragan-2M power supply for magnetic coils.
- Continue wall conditioning and discharge start-up studies in collaboration with LPP-RMA.
- Continue fusion-fission hybrid studies in collaboration with Uppsala University.
- Continue HIBP experimental studies at TJ-II.

6.6 USA

6.6.1 **PPPL collaboration on W7-X**

PPPL had two full time research scientists (Pablant, Lazerson) on site for the entire calendar year. Additionally there was one PPPL graduate student (LeViness) who was supported in part by PPPL and in part by a Fulbright scholarship.

Dr. Novimir Pablant, in close collaboration with Dr. A. Langenberg, operated the XICS diagnostic and ran numerous (~30) transport focused experiments. He was also the co-lead of the impurity transport group for the CWGM.

Dr. Samuel Lazerson from PPPL continued to serve as the Scenario and Integration Task Force leader for the OP1.2b experimental campaign on W7-X. He continued his work with Dr. Jakubowski, Dr. Geiger, and Dr. Bozhenkov to actuate divertor heat loads using magnetic coils on W7-X. Dr. Lazerson led work to characterize the fueling of the main gas valve system on W7-X. In collaboration with Dr. Äkäslompolo, Dr. Ford, and Dr. Hartman. Dr. Lazerson has also has led experiments to investigate purely NBI heated plasmas.

Alexandra LeViness analysed Halpha emissions in the divertor working with Dr. Thomas Sunn Pederson.

Dr. Robert Lunsford designed, built, installed, and operated the Probe Mounted Powder Injector in collaboration with Dr. Carston Killer.

6.6.2 LANL Collaboration with W7-X

Glen Wurden of LANL spent the bulk of the calendar year at IPP Greifswald. Major activities were:

- Construction, testing, installation, and operation of the combined IR, visible, UV scraper element imaging system for OP1.2b. Wurden, Fellinger
- Successful testing of prototype scraper elements in W7-X on Sept 25, 2018. Wurden, Yu, Lore, Hammond, Fellinger, et al.

IR observation of OP2.0 water-cooled divertor elements in the GLADIS NB test stand, at up to 10 MW/m^2 heat loads. Wurden, Gruener, Boscary, During 2019, ongoing Data Analysis from OP1.2b. In particular:

1. Comparing scraper element experimental performance to prior modelling.
2. Investigating improved performance for certain magnetic configurations (iota effects)
3. Investigating ELM-like and ELM, low frequency fluctuations and their effects on confinement in W7-X.
4. Investigating pellet injection effects (beyond the obvious density increases) in W7-X plasmas.
5. Analyzing damage (burn) patterns on W7-X divertor components with inspection photography, and comparing with IR strike-lines. Basically, integrating post-mortem analysis with other observations during the campaign.

During 2019, supporting OP2.0 diagnostic upgrades. In particular, the new big endoscope design led by Joris Fellinger, as well as repurposing and upgrading (with water-cooling) the QSR07 IR imaging diagnostic, possibly for high resolution observation of the high-iota divertor region.

6.6.3 MIT collaboration with W7-X

Work done in 2018 as part of the MIT-W7X collaboration on Gas-Puff-Imaging has involved 1) operation of a fast-framing camera (see Section 6.5), 2) analysis of data from that camera and other W7-X diagnostics, and 3) continued work on the design and procurement of a Gas-Puff-Imaging diagnostic for use during W7-X's OP 2. This Gas-Puff-Imaging diagnostic will enable detailed study of edge turbulence. Four different MIT staff have been involved with this task.

Initial PCI studies of the turbulence indicate that there are significant changes in both the amplitude and wavenumber distribution of the density fluctuations under variations in the magnetic configuration. Even more dramatic results have been obtained with pellet fuelling of W7-X plas-mas. The PCI measurements indicate that during pellet fuelling, as the density rises and the density profile is peaked, once fuelling is completed, the turbulence level suddenly decreases and con-comitantly, the global energy confinement increases.

In addition to turbulent spectra, coherent Alfvén waves have been observed across a relatively wide range of plasma conditions with only ECR heating. Given the absence of any direct ion heating mechanism that would create high-energy ions, it must be concluded that these waves are excited by the gradients of plasma electrons (or trapped particles). This is an unexpected phenomenon, and further studies are underway to identify the physics of wave excitation.

6.6.4 University of Wisconsin-Madison collaborations with LHD and W7-X

Aaron Bader had two open collaborations with the NIFS group. One is on EMC3-EIRENE simulations of LHD (main contacts are Gakushi Kawamura and Masahiro Kobayashi. The other is on optimization in general, with Yasuhiro Suzuki being the main contact. Dr. Bader recently visited NIFS to work on these collaborations and also attend the JSPF conference and optimization workshop.

Another collaboration for Dr. Bader project is with Michael Drevlak and Sophia Henneberg at IPP on stellarator optimization. Michael visited UW-Madison in the summer, and we've been communicating regularly since then. A journal article on energetic particle optimization is under preparation which is a direct result of this collaboration.

The University of Wisconsin-Madison (P.I. David Smith) is assessing the feasibility of a fluctuation beam emission spectroscopy diagnostic system for 2D measurements of turbulence fields in W7-X to advance the physics understanding of turbulence and transport in neoclassically-optimized stellarators.

The activities of UW Madison focused on island divertor physics have resulted in installation, commissioning and successful use of three diagnostic systems: a thermal helium beam (measuring electron density and temperature in the island divertor), the Wisconsin In-Situ Penning (WISP) gauges (measuring fractional neutral and impurity pressures in the island divertor baffle and in the main chamber) and the Oak Ridge Filter Scope system. All diagnostics are completely implemented, including delivery of data into the W7-X web-archive. Three dedicated experiments on "Radiative Edge Cooling " (PhD student F. Effenberg), "Hydrogen and Helium exhaust in the island divertor" (PhD student T. Kremeyer) and "Impurity sourcing and edge impurity transport" (PhD student V. Winters) have been planned and executed in the last campaign (OP1.2b) at W7-X. EMC3-EIRENE modelling on radiative edge cooling and general island divertor physics studies have been continued and the results were used in planning and execution of several experiments across the W7-X plasma edge physics team. A new coupling of VMEC results into EMC3-EIRENe has been developed jointly by Dr. J. Schmitt (Auburn University) and Dr. H. Frerichs (UW Madison). This tool is presently being exercised based on first dedicated discharges at W7-X with significant equilibrium effects on divertor target heat fluxes. Prof. O. Schmitz participated in planning and execution of collaborative experiments on plasma fuelling, exhaust and divertor detachment. He has been invited to deliver a talk on the upcoming EPS conference 2019.

A dedicated test stand for calibration of the Laser Blow Off targets and investigation of the ablation properties has been setup and commissioned at UW Madison. This test stand and analysis capabilities in the UW Madison Material Science Centre have been used to provide quantitative numbers of the material amounts injected.

Analysis of a series of experiments addressing impurity exhaust with the Closed Helical Divertor (CHD) at LHD led by Prof. O. Schmitz is commencing utilizing EMC3-EIRENe modelling and new CXRS data from Dr. Ida et al.. A Letter has been published in Nuclear Fusion on first experiments with the completely actively cryo-cooled CHD at LHD.

6.6.5 **ORNL collaboration with W7-X**

ITER prototype fast diagnostic gas analyzer developed by ORNL was installed, commissioned and operated during operational period OP 1.2b, demonstrating performance (~1 sec response times) required for ITER and data on multi-gas fueling.

The divertor scraper elements developed by ORNL/PPPL/IPP were installed in W7-X and experiments with high beta mimic configuration scans were carried out. The data are being used to validate simulations of heat flux deposition during high beta evolution so as to develop divertor protection schemes.

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 was developed by ORNL/PPPL/IPP and approved by both the US Dept of Energy (DOE) and the Max-Planck IPP governing board. Initial funding for the US hardware development work was provided by DOE.

Dr. Jeremy Lore led experiments in OP1.2a and OP1.2b to characterize divertor fluxes and pumping efficiency in magnetic configurations designed to mimic plasma evolution in high performance OP2 discharges. The protection of divertor edges via the scraper element was confirmed in the OP1.2b experiments.

6.6.6 **Auburn with W7-X**

Auburn University is involved with 3D equilibrium reconstruction of the plasmas using available diagnostics including magnetics, Thomson scattering, ECE, soft x-ray, and interferometry. Auburn is also involved with the modeling and measurement of the time evolution of the net toroidal currents, including the self-driven bootstrap current and ECCD (electron cyclotron current drive). In OP1.2b, Auburn has used the V3FIT equilibrium reconstruction code to help analyze the pressure and current profiles in the W7-X plasmas with magnetic diagnostic signals and is beginning to incorporate more internal diagnostics to constrain profile fits. Software development continues for the analysis and expansion of the V3FIT codebase. Dr. John Schmitt was onsite for the OP1.2b run campaign from July through October of 2018.

Auburn University is also involved in day-to-day operations and data analysis of the X-ray Imaging Crystal Spectrometer (XICS) in conjunction with Dr. Novimir Pablant of PPPL during OP1.2b. A graduate student, Peter Traverso, will be on-site for the entire duration of OP.2b from April to October of 2018. He is expected to graduate in 2019. A second Auburn graduate student finalized the design (final design review with PPPL August 2018) of an in-situ absolute x-ray calibration system in collaboration with Dr. Pablant and Dr. Maurer for the XICS with tentative planned installation post OP1.2b.

In addition to the equilibrium reconstruction and XICS activities, Auburn University has been active on the W7-X Coherence Imaging System (CIS) implemented for OP1.2b. Dr. David Ennis spent 6 weeks this summer on-site at IPP from mid-June through August 2018 working with the IPP graduate student running the diagnostic. This diagnostic development and implementation have led to the first measurements of counter-streaming plasma flows in the island divertor region of W7-X suing the OP1.2b campaign.

In addition, Dr. David Maurer spent approximately a week at W7-X in the month of July helping coordinate Auburn group activities on the experiment.

6.6.7 **Xantho Technologies for W7-X Development**

The long-term aim of this program is a detailed study of the Wendelstein 7-X plasma interior using a Heavy Ion Beam Probe (HIBP) diagnostic. Work has shown that implementation of an HIBP on W7-X is feasible. Within each of the eight W7-X reference magnetic configurations (assuming B tor is in the $-\phi$ direction), equilibrium electrostatic potential measurements will be possible from the plasma core to the edge, and broadband ion-scale fluctuation measurements will be possible in (at least) the outer region.

This Xantho/W7-X collaboration, is in its second phase - advancing the development of an HIBP diagnostic toward installation onto W7-X. Efforts during the past year have used computer modeling to advance the system design. The expected spatial resolution and wavenumber sensitivity of the diagnostic have been improved by modifying the anticipated energy analyzer location and by changing the initial beam focus to take advantage of the system's ion optics. Secondary beam steering system options (which reduce the voltage and/or space requirements), and ion optics models and analysis codes for the primary beamline, have been developed.

7 Annex

7.1 Names of personnel participating in experiments

Country	Institution	Experiment	Name
Australia	ANU	W7-X	B. Blackwell
EU: Belgium	LPP-ERM-KMS	W7-X	T. Wauters
EU: Belgium	LPP-ERM-KMS	W7-X	Y. Kazakov
EU: Denmark	DTU	W7-X	S. K. Nielsen
EU: Finland	VTT	W7-X	A. Hakola
EU: Finland	VTT	W7-X	J. Kontula
EU: France	CEA	W7-X	Y. Corre
EU: Germany	FZJ	W7-X	A. Kirschner
EU: Germany	FZJ	W7-X	A. Knieps
EU: Germany	FZJ	W7-X	C. Li
EU: Germany	FZJ	W7-X	D. Nicolai
EU: Germany	FZJ	W7-X	E. Wang
EU: Germany	FZJ	W7-X	G. Satheeswaran
EU: Germany	FZJ	W7-X	J. Cai
EU: Germany	FZJ	W7-X	J. Oelmann
EU: Germany	FZJ	W7-X	J. Romazanov
EU: Germany	FZJ	W7-X	J.W. Coenen
EU: Germany	FZJ	W7-X	K.P. Hollfeld
EU: Germany	FZJ	W7-X	M. Jia
EU: Germany	FZJ	W7-X	O. Marchuk
EU: Germany	FZJ	W7-X	Ph. Drews
EU: Germany	FZJ	W7-X	S. Brezinsek
EU: Germany	FZJ	W7-X	S. Sereda
EU: Germany	FZJ	W7-X	T. Dittmar
EU: Germany	FZJ	W7-X	X. Han
EU: Germany	FZJ	W7-X	Y. Li
EU: Germany	FZJ	W7-X	Y. Liang
EU: Germany	IPP Greifswald	LHD	J.P. Koschinsky
EU: Germany	IPP Greifswald	LHD	S. Äkäslompolo
EU: Germany	IPP Greifswald	LHD	S. Bozhenkov
EU: Hungary	Wigner RCP	W7-X	D. Dunai
EU: Hungary	Wigner RCP	W7-X	G. Anda
EU: Hungary	Wigner RCP	W7-X	G. Cseh
EU: Hungary	Wigner RCP	W7-X	G. Kocsis
EU: Hungary	Wigner RCP	W7-X	L.Z. Zsuga
EU: Hungary	Wigner RCP	W7-X	M. Vecsei
EU: Hungary	Wigner RCP	W7-X	S. Zoletnik
EU: Hungary	Wigner RCP	W7-X	T. Szabolics

EU: Hungary	Wigner RCP	W7-X	T. Szepesi
EU: Italy	ENEA - RFX	W7-X	G. Grenfell
EU: Italy	ENEA - RFX	W7-X	M. Spolaore
EU: Italy	ENEA - RFX	W7-X	O. McCormack
EU: Italy	ENEA - RFX	W7-X	P. Agostinetti
EU: Italy	ENEA - UC	W7-X	A. Fanni
EU: Italy	ENEA - UC	W7-X	B. Cannas
EU: Italy	ENEA - UC	W7-X	F. Pisano
EU: Italy	ENEA - UC	W7-X	G. Sias
EU: Poland	IPPLM	W7-X	A. Czarnecka
EU: Poland	IPPLM	W7-X	I. Ksiazek
EU: Poland	IPPLM	W7-X	M. Gruca
EU: Poland	IPPLM	W7-X	M. Kubkowska
EU: Poland	IPPLM	W7-X	M. Sleczka
EU: Poland	IPPLM	W7-X	N. Krawczyk
EU: Poland	IPPLM	W7-X	T. Fornal
EU: Portugal	IST	TJ-II	R. Sharma
EU: Spain	CIEMAT	W7-X	D. Carralero
EU: Spain	CIEMAT	W7-X	E. Ascasibar
EU: Spain	CIEMAT	W7-X	F. Tabarés
EU: Spain	CIEMAT	W7-X	J. L. Velasco
EU: Spain	CIEMAT	W7-X	J. M. García-Regaña
EU: Spain	CIEMAT	W7-X	K. McCarthy
EU: Spain	CIEMAT	W7-X	T. Estrada
EU: Spain	NIFS	LHD	K. McCarthy
Japan	Kyoto University	TJ-II	S. Kobayashi
Japan	Kyoto University	HSX	S. Kobayashi
Japan	Kyoto University	TJ-II	S. Ohshima
Japan	Kyoto University	HSX	S. Ohshima
Japan	NIFS	W7-X	B. Peterson
Japan	NIFS	W7-X	G. Motojima
Japan	NIFS	TJ-II	H. Takahashi
Japan	NIFS	W7-X	H. Tsuchiya
Japan	NIFS	W7-X	K. Ida
Japan	NIFS	W7-X	K. Ogawa
Japan	NIFS	W7-X	M. Isobe
Japan	NIFS	W7-X	M. Ysohinuma
Japan	NIFS	W7-X	N. Ashikawa
Japan	NIFS	W7-X	N. Tamura
Japan	NIFS	W7-X	S. Masuzaki
Japan	NIFS	W7-X	T. Akiyama
Japan	NIFS	TJ-II	T. Kobayashi

Russia	Kurchatov Institute	TJ-II	A. Melnikov
Russia	Kurchatov Institute	TJ-II	L.G. Eliseev
Russia	Kurchatov Institute	TJ-II	N.K. Kharchev
Russia	Kurchatov Institute	TJ-II	Ph. Khabanov
Ukraine	NSC KIPT	TJ-II	A. Chmyga
Ukraine	NSC KIPT	TJ-II	A.S. Kozachek
Ukraine	NSC KIPT	TJ-II	L.I. Krupnik
Ukraine	NSC KIPT	TJ-II	V. Volkov
Ukraine	NSC KIPT	W7-X	A. Beletskiy
Ukraine	NSC KIPT	W7-X	D.A. Sitnikov
Ukraine	NSC KIPT	W7-X	E.L. Sorokovoi
Ukraine	NSC KIPT	W7-X	M.B. Dreval
Ukraine	NSC KIPT	TCV	M.B. Dreval
Ukraine	NSC KIPT	W7-X	V.B. Korovin
Ukraine	NSC KIPT	W7-X	V.E. Moiseenko
USA	Auburn U	W7-X	D. Maurer
USA	Auburn U	W7-X	J.C. Schmitt
USA	Auburn U	W7-X	P. Traverso
USA	DOE (LANL)	W7-X	G.A. Wurden
USA	MIT	W7-X	J. Terry
USA	MIT	W7-X	K. Tang
USA	MIT	W7-X	S. Ballinger
USA	MIT	W7-X	S.G. Baek
USA	ORNL	W7-X	A. Lumsdaine
USA	ORNL	W7-X	J. Harris
USA	ORNL	W7-X	J. Lore
USA	PPPL	W7-X	A. LeViness
USA	PPPL	W7-X	D.A. Gates
USA	PPPL	W7-X	N. Pablant
USA	PPPL	W7-X	R. Lunsford
USA	PPPL	W7-X	S. Lazerson
USA	UW-Madison	LHD	A. Bader
USA	UW-Madison	W7-X	B. Meyers
USA	UW-Madison	W7-X	D. Smith
USA	UW-Madison	W7-X	E. Flom
USA	UW-Madison	W7-X	F. Effenberg
USA	UW-Madison	W7-X	I. Ioda
USA	UW-Madison	LHD	O. Schmitz
USA	UW-Madison	W7-X	O. Schmitz
USA	UW-Madison	W7-X	T. Barbui
USA	UW-Madison	W7-X	T. Kremeyer
USA	UW-Madison	W7-X	V. Winters

USA	West Virginia University	TJ-II	M. Koepke
USA	Xantho Technologies LLC	W7-X	D.R. Demers
USA	Xantho Technologies LLC	W7-X	P.J. Fimognari
USA	Xantho Technologies LLC	W7-X	T.P. Crowley

7.2 List of scientist exchanges

(List of scientist exchanges for collaborative work; it is not necessary to list simple conference attendance)

Country	Institution	Name	Dates	Location
EU: Denmark	DTU	A. Tancetti	08/20/2018 - 08/30/2018	IPP Greifswald, Germany
EU: Denmark	DTU	A. Tancetti	09/17/2018 - 09/21/2018	IPP Greifswald, Germany
EU: Denmark	DTU	C. Mollsoe	10/01/2018 - 10/02/2018	IPP Greifswald, Germany
EU: Denmark	DTU	M. Jessen	06/20/2018	IPP Greifswald, Germany
EU: Denmark	DTU	S.K. Nielsen	06/20/2018	IPP Greifswald, Germany
EU: Denmark	DTU	T. Jensen	06/06/2018 - 06/07/2018	IPP Greifswald, Germany
EU: Denmark	DTU	T. Jensen	10/01/2018 - 10/02/2018	IPP Greifswald, Germany
EU: France	U Nancy	K. Camacho	05/21/2018 - 06/01/2018	IPP Greifswald, Germany
EU: France	U Nancy	K. Camacho	11/19/2018 - 11/30/2018	IPP Greifswald, Germany
EU: Germany	IPP	A. Mollén	12/02/2018 - 12/15/2018	U Maryland, USA
EU: Germany	IPP	B. Shanahan	02/11/2018 - 02/17/2018	U York, United Kingdom
EU: Germany	IPP	B. Shanahan	12/03/2018 - 12/07/2018	U York, United Kingdom
EU: Germany	IPP	G. Plunk	03/19/2018 - 03/31/2018	NIFS, Japan
EU: Germany	IPP	J. Baldzuhn	02/23/2018 - 03/04/2018	ORLN, USA
EU: Germany	IPP	J. Geiger	02/03/2018 - 03/03/2018	NIFS, Japan
EU: Germany	IPP	J.P. Koschinsky	08/03/2018 - 08/18/2017	NIFS, Japan

EU: Germany	IPP	M. Drevlak	08/18/2018 - 08/24/2018	UW-Madison, USA
EU: Germany	IPP	N. Marushchenko	04/08/2018 - 04/25/2018	U Kharkov, United Kingdomraine
EU: Germany	IPP	O. Mishchenko	09/06/2018 - 09/14/2018	U Kharkov, United Kingdomraine
EU: Germany	IPP	P. Drewelow	11/17/2017 - 11/30/2017	NIFS, Japan
EU: Germany	IPP	P. Helander	02/03/2018 - 02/15/2018	MIT, USA
EU: Germany	IPP	P. Helander	02/19/2018 - 02/21/2018	U Carlos III, Madrid, Spain
EU: Germany	IPP	P. Helander	04/21/2018 - 04/27/2018	PPPL, USA
EU: Germany	IPP	S. Henneberg	05/13/2018 - 05/27/2018	PPPL / U Maryland, USA
EU: Germany	U Aachen	S. Braun	05/24/2018 - 05/26/2018	IPP Greifswald, Germany
EU: Italy	U Padua	G. Moro	04/04/2018 - 04/30/2018	IPP Greifswald, Germany
EU: Netherlands	TU Eindhoven	C. Mora Moreno	02/02/2018 - 02/16/2018	IPP Greifswald, Germany
EU: Netherlands	TU Eindhoven	C. Mora Moreno	06/01/2018 - 09/14/2018	IPP Greifswald, Germany
EU: Netherlands	TU Eindhoven	C.P. Stylianidis	05/06/2018 - 05/19/2018	IPP Greifswald, Germany
EU: Netherlands	TU Eindhoven	C.P. Stylianidis	07/28/2018 - 08/31/2018	IPP Greifswald, Germany
EU: Netherlands	TU Eindhoven	J. Proll	06/06/2018 - 09/30/2018	IPP Greifswald, Germany
EU: Netherlands	TU Eindhoven	N. Chennakeshawa	06/03/2018 - 08/18/2018	IPP Greifswald, Germany
EU: Netherlands	TU Eindhoven	T. Neelis	06/07/2018 - 11/30/2018	IPP Greifswald, Germany
EU: Poland	IPPLM Warsaw	G. Pelka	11/11/2018 - 11/24/2018	IPP Greifswald, Germany
EU: Portugal	IST Lisboa	B. Brotas de Carvalho	06/25/2018 - 06/29/2018	IPP Greifswald, Germany
EU: Spain	CIEMAT	D. Carralero	09/05/2018 - 10/18/2018	IPP Greifswald, Germany

EU: Spain	CIEMAT	E. Ascasíbar	08/20/2018 - 08/31/2018	IPP Greifswald, Germany
EU: Spain	CIEMAT	F. Tabarés	08/01/2018 - 08/07/2018	IPP Greifswald, Germany
EU: Spain	CIEMAT	J. L. Velasco	09/24/2018 - 10/05/2018	IPP Greifswald, Germany
EU: Spain	CIEMAT	J. M. G. Regaña	10/01/2018 - 10/12/2018	IPP Greifswald, Germany
EU: Spain	CIEMAT	K. McCarthy	09/04/2018	IPP Greifswald, Germany
EU: Spain	CIEMAT	T. Estrada	07/25/2018 - 08/07/2018	IPP Greifswald, Germany
EU: Sweden	Chalmers U	Pontus Svensson	06/04/2018 - 07/13/2018	IPP Greifswald, Germany
EU: UK	U Oxford	A. von Boetticher	11/11/2018 - 11/12/2018	IPP Greifswald, Germany
EU: UK	U Oxford	S. Dudarev	01/25/2018 - 01/26/2018	IPP Greifswald, Germany
EU: UK	U York	S. Orchard	07/02/2018 - 09/07/2018	IPP Greifswald, Germany
EU: UK	INR Kiev	A. Tykhyy	12/02/2018 - 12/08/2018	IPP Greifswald, Germany
EU: UK	INR Kiev	Y. Kolesnichenko	12/02/2018 - 12/08/2018	IPP Greifswald, Germany
EU: UK	NSC KIPT	A. Beletskiy	07/15/2018 - 07/28/2018	IPP Greifswald, Germany
EU: UK	NSC KIPT	A.A. Chmyga	04/02/2018 - 05/26/2018	CIEMAT, Spain
EU: UK	NSC KIPT	A.A. Chmyga	11/05/2018 - 12/21/2018	CIEMAT, Spain
EU: UK	NSC KIPT	A.S. Kozachek	04/02/2018 - 05/26/2018	CIEMAT, Spain
EU: UK	NSC KIPT	A.S. Kozachek	11/05/2018 - 12/21/2018	CIEMAT, Spain
EU: UK	NSC KIPT	D.A. Sitnikov	07/23/2018 - 07/27/2018	IPP Greifswald, Germany
EU: UK	NSC KIPT	E.L. Sorokovoi	07/16/2018 - 07/27/2018	IPP Greifswald, Germany
EU: UK	NSC KIPT	L.I. Krupnik	04/04/2018 - 04/19/2018	CIEMAT, Spain
EU: UK	NSC KIPT	M.B. Dreval	08/18/2018 - 09/01/2018	IPP Greifswald, Germany

EU: UK	NSC KIPT	M.B. Dreval	10/01/2018 - 10/05/2018	EPFL, Switzerland
EU: UK	NSC KIPT	S.V.Kasilov	02/2018 - 03/2018	TU Graz, Austria
EU: UK	NSC KIPT	S.V.Kasilov	06/2018 - 08/2018	TU Graz, Austria
EU: UK	NSC KIPT	S.V.Kasilov	11/2018 - 12/2018	TU Graz, Austria
EU: UK	NSC KIPT	V. Volkov	11/05/2018 - 11/17/2018	CIEMAT, Spain
EU: UK	NSC KIPT	V.B. Korovin	07/16/2018 - 07/27/2018	IPP Greifswald, Germany
EU: UK	NSC KIPT	V.E. Moiseenko	02/13/2018 - 02/15/2018	Stockholm, Sweden
EU: UK	NSC KIPT	V.E. Moiseenko	07/15/2018 - 07/28/2018	IPP Greifswald, Germany
EU: UK	NSC KIPT	V.E. Moiseenko	12/18/2017 - 01/28/2018	U Uppsala, Sweden
Japan	Bunko-Keiki company	Y. Lida	03/12/2018 - 03/16/2018	IPP Greifswald, Germany
Japan	Bunko-Keiki Company	Y. Nakamura	06/25/2018 - 06/29/2018	IPP Greifswald, Germany
Japan	Kyoto University	S. Kobayashi	03/04/2018 - 03/11/2018	UW-Madison, USA
Japan	Kyoto University	S. Kobayashi	03/19/2018 - 03/23/2018	CIEMAT, Spain
Japan	Kyoto University	S. Kobayashi	12/03/2018 - 12/09/2018	ORLN, USA
Japan	Kyoto University	S. Ohshima	03/26/2018 - 03/31/2018	CIEMAT, Spain
Japan	Kyoto University	S. Ohshima	09/15/2018 - 02/10/2018	UW-Madison, USA
Japan	NIFS	B. Peterson	06/24/2018 - 06/30/2018	IPP Greifswald, Germany
Japan	NIFS	C. SuzEU: United Kingdomi	09/10/2018 - 09/12/2018	IPP Greifswald, Germany
Japan	NIFS	G. Motojima	08/30/2018 - 09/15/2018	IPP Greifswald, Germany
Japan	NIFS	H. Kasahara	04/22/2018 - 04/29/2018	IPP Greifswald, Germany
Japan	NIFS	H. Takahashi	03/26/2018 - 03/29/2018	CIEMAT, Spain

Japan	NIFS	H. Tsuchiya	09/23/2018 - 09/29/2018	IPP Greifswald, Germany
Japan	NIFS	K. Ichiguchi	06/26/2018 - 06/29/2018	U Carlos III, Madrid, Spain
Japan	NIFS	K. Ida	03/12/2018 - 03/16/2018	IPP Greifswald, Germany
Japan	NIFS	K. Ida	06/25/2018 - 06/29/2018	IPP Greifswald, Germany
Japan	NIFS	K. Ida	08/20/2018 - 08/24/2018	IPP Greifswald, Germany
Japan	NIFS	K. Ida	09/16/2018 - 09/21/2018	IPP Greifswald, Germany
Japan	NIFS	K. Ogawa	08/16/2018 - 08/28/2018	IPP Greifswald, Germany
Japan	NIFS	K. Ogawa	02/25/2018 - 03/01/2018	IPP Greifswald, Germany
Japan	NIFS	K. Ogawa	07/08/2018 - 07/12/2018	IPP Greifswald, Germany
Japan	NIFS	M. Isobe	02/24/2018 - 03/01/2018	IPP Greifswald, Germany
Japan	NIFS	M. Nakata	04/09/2018 - 04/14/2018	PPPL, USA
Japan	NIFS	M. Nakata	06/18/2018 - 09/14/2018	IPP Greifswald, Germany
Japan	NIFS	M. Yokoyama	04/08/2018 - 04/14/2018	PPPL, USA
Japan	NIFS	M. Yokoyama	04/22/2018 - 04/29/2018	IPP Greifswald, Germany
Japan	NIFS	M. Yoshinuma	06/24/2018 - 07/01/2018	IPP Greifswald, Germany
Japan	NIFS	M. Yoshinuma	08/19/2018 - 08/26/2018	IPP Greifswald, Germany
Japan	NIFS	M. Yoshinuma	09/15/2018 - 09/23/2018	IPP Greifswald, Germany
Japan	NIFS	M. Yoshinuma	03/12/2018 - 03/16/2018	IPP Greifswald, Germany
Japan	NIFS	N. Ashikawa	03/16/2018 - 03/23/2018	IPP Greifswald, Germany
Japan	NIFS	N. Tamura	01/22/2018 - 02/04/2018	IPP Greifswald, Germany
Japan	NIFS	N. Tamura	03/11/2018 - 03/31/2018	IPP Greifswald, Germany

Japan	NIFS	N. Tamura	04/08/2018 - 04/14/2018	PPPL, USA
Japan	NIFS	N. Tamura	05/26/2018 - 06/10/2018	IPP Greifswald, Germany
Japan	NIFS	N. Tamura	07/07/2018 - 07/14/2018	IPP Greifswald, Germany
Japan	NIFS	N. Tamura	07/21/2018 - 08/12/2018	IPP Greifswald, Germany
Japan	NIFS	N. Tamura	09/01/2018 - 09/30/2018	IPP Greifswald, Germany
Japan	NIFS	S. Masuzaki	03/12/2018 - 03/25/2018	IPP Greifswald, Germany
Japan	NIFS	S. Satake	09/17/2018 - 09/21/2018	CIEMAT, Spain
Japan	NIFS	T. Akiyama	09/12/2018 - 09/21/2018	IPP Greifswald, Germany
Japan	NIFS	T. Kobayashi	01/12/2018 - 02/12/2018	CIEMAT, Spain
Japan	NIFS	Y. SuzEU: United King-domi	04/09/2018 - 04/22/2018	PPPL, USA
Japan	NIFS	Y. SuzEU: United King-domi	09/09/2018 - 09/16/2018	UW-Madison, USA
Japan	U Tokyo	M. Nishiura	02/26/2018 - 02/28/2018	IPP Greifswald, Germany
Russia	Kurchatov Institute	A. Melnikov	09/04/2018 - 01/06/2018	CIEMAT, Spain
Russia	Kurchatov Institute	A. Melnikov	10/12/2018 - 20/12/2018	CIEMAT, Spain
Russia	Kurchatov Institute	L.G. Eliseev	11/07/2018 - 12/21/2018	CIEMAT, Spain
Russia	Kurchatov Institute	L.G. Eliseev	04/09/2018 - 05/26/2018	CIEMAT, Spain
Russia	Kurchatov Institute	N.K. Kharchev	11/05/2018 - 12/07/2018	CIEMAT, Spain
Russia	Kurchatov Institute	Ph. Khabanov	11/04/2018 - 12/20/2018	CIEMAT, Spain
Russia	Kurchatov Institute	Ph. Khabanov	05/14/2018 - 06/30/2018	CIEMAT, Spain
Russia	Kurchatov Moscow	M. Mikhailov	02/19/2018 - 03/28/2018	IPP Greifswald, Germany
Switzerland	EPFL Lausanne	J. Loizu	06/18/2018 - 06/29/2018	IPP Greifswald, Germany

USA	DOE/LANL	G.A. Wurden	10/01/2017 - 11/02/2018	IPP Greifswald, Germany
USA	MIT	A. Marioni	07/16/2018 - 08/15/2018	IPP Greifswald, Germany
USA	MIT	E. Davis	07/09/2018 - 08/15/2018	IPP Greifswald, Germany
USA	MIT	M. Porkolab	10/14/2018 - 10/18/2018	IPP Greifswald, Germany
USA	MIT	R. Lunsford	09/17/2018 - 09/28/2018	IPP Greifswald, Germany
USA	MIT	S. Ballinger	04/21/2018 - 04/29/2018	IPP Greifswald, Germany
USA	MIT	S. Ballinger	07/06/2018 - 09/02/2018	IPP Greifswald, Germany
USA	MIT	Z. Huang	02/01/2018 - 12/31/2018	IPP Greifswald, Germany
USA	MIT/ PSFC	E. Edlund	06/01/2018 - 08/17/2018	IPP Greifswald, Germany
USA	ORNL	J. Harris	07/23/2018 - 11/30/2018	IPP Greifswald, Germany
USA	ORNL	J. Lore	04/22/2018 - 04/28/2018	IPP Greifswald, Germany
USA	ORNL	J. Lore	09/22/2018 - 09/28/2018	IPP Greifswald, Germany
USA	ORNL	J. Lore	11/25/2017 - 12/02/2017	IPP Greifswald, Germany
USA	PPPL	A. LeViness	01/01/2018 - 08/31/2018	IPP Greifswald, Germany
USA	PPPL	D.A. Gates	06/10/2018 - 06/16/2018	NIFS, Japan
USA	PPPL	D.A. Gates	07/16/2018 - 07/20/2018	IPP Greifswald, Germany
USA	PPPL	D.A. Gates	09/24/2018 - 09/28/2018	IPP Greifswald, Germany
USA	PPPL	D.A. Gates	10/01/2018 - 10/05/2018	IPP Greifswald, Germany
USA	PPPL	D.A. Gates	12/10/2018 - 12/14/2018	IPP Greifswald, Germany
USA	PPPL	M. Porkolab	09/03/2018 - 09/07/2018	IPP Greifswald, Germany
USA	PPPL	N. Pablant	01/01/2018 - 12/31/2018	IPP Greifswald, Germany

USA	PPPL	R. Lunsford	09/17/2018 - 09/28/2018	IPP Greifswald, Germany
USA	PPPL	S. Lazerson	01/01/2018 - 12/31/2018	IPP Greifswald, Germany
USA	SUNY Cortland	N. Rose	06/18/2018 - 07/31/2018	IPP Greifswald, Germany
USA	U Auburn	D. Ennis	06/15/2018 - 08/31/2018	IPP Greifswald, Germany
USA	U Auburn	D. Maurer	07/07/2018 - 07/14/2018	IPP Greifswald, Germany
USA	U Auburn	D. Maurer	07/23/2018 - 07/26/2018	IPP Greifswald, Germany
USA	U Auburn	J.C. Schmitt	06/25/2018 - 10/15/2018	IPP Greifswald, Germany
USA	U Auburn	J.C. Schmitt	04/22/2018 - 05/04/2018	IPP Greifswald, Germany
USA	U Auburn	P. Traverso	04/01/2018 - 10/31/2018	IPP Greifswald, Germany
USA	U Maryland	E. Paul	06/03/2018 - 06/09/2018	IPP Greifswald, Germany
USA	UW-Madison	A. Bader	12/03/2018 - 12/07/2018	NIFS, Japan
USA	UW-Madison	D. Smith	12/11/2018 - 12/16/2018	IPP Greifswald, Germany
USA	UW-Madison	E. Flom	06/01/2018 - 12/31/2018	IPP Greifswald, Germany
USA	UW-Madison	F. Effenberg	01/01/2018 - 12/21/2018	IPP Greifswald, Germany
USA	UW-Madison	H. Frerichs	03/10/2018 - 03/22/2018	IPP Greifswald, Germany
USA	UW-Madison	J. Smoniewski	08/15/2018 - 10/22/2018	IPP Greifswald, Germany
USA	UW-Madison	O. Schmitz	07/04/2018 - 08/28/2018	IPP Greifswald, Germany
USA	UW-Madison	T. Barbui	01/01/2018 - 12/31/2018	IPP Greifswald, Germany
USA	UW-Madison	T. Kremeyer	01/01/2018 - 12/31/2018	IPP Greifswald, Germany
USA	UW-Madison	V. Winters	01/01/2018 - 12/31/2018	IPP Greifswald, Germany
USA	Yale U	J. Swerdlow	05/27/2018 - 08/25/2018	IPP Greifswald, Germany

USA	NYU	H. Weitzner	10/15/2018 - 10/26/2018	IPP Greifswald, Germany

7.3 List of journal articles

Please use the following citation format or something close to it if possible.

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Adlparvar, S., Miraboutalebi, S., Sadat Kiai, S. M. & Rajaee, L. Study on resonant electron cyclotron heating by OSXB double mode conversion at the W7-X stellarator. Nuclear Engineering and Technology 50, 1106-1111, doi:10.1016/j.net.2018.06.013 (2018).
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Baldzuhn, J. et al. Particle fueling experiments with a series of pellets in LHD. Plasma Physics and Controlled Fusion 60, doi:10.1088/1361-6587/aaa184 (2018).
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Ballinger, S. et al. Fast camera imaging of plasmas in Alcator C-Mod and W7-X. Nuclear Materials and Energy 17, 269-273, doi:10.1016/j.nme.2018.11.015 (2018).
Bando, T. et al. Excitation of helically-trapped-energetic-ion driven resistive interchange modes with intense deuterium beam injection and enhanced effect on beam ions/bulk plasmas of LHD. Nuclear Fusion 58, doi:10.1088/1741-4326/aac699 (2018).
Bando, T. et al. Simultaneous excitation of the snake-like oscillations and the m/n = 1/1 resistive interchange modes around the iota = 1 rational surface just after hydrogen pellet injections in LHD plasmas. Physics of Plasmas 25, doi:10.1063/1.5003058 (2018).
Barbui, T. et al. The He/Ne beam diagnostic for active emission spectroscopy in the island divertor of Wendelstein 7-X. 45th EPS Conference on Plasma Physics, EPS 2018 2018-July, 1025-1027 (2018).
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Beidler, C. D. et al. (Expected difficulties with) density-profile control in W7-X high-performance plasmas. Plasma Physics and Controlled Fusion 60, doi:10.1088/1361-6587/aad970 (2018).
Böckenhoff, D. et al. Reconstruction of magnetic configurations in W7-X using artificial neural networks. Nuclear Fusion 58, doi:10.1088/1741-4326/aab22d (2018).
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