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CONTENT

HISTORICAL CONTEXT

The report overviews the research in the field of nuclear fusion performed by the EURATOM/LEI association during the FP7 programme, which covers the period 2007 to 2013. Throughout this period EURATOM/LEI published detailed Annual reports presenting activities performed each year. All these reports are included in DVD with this report. This report highlights the main areas of activities funded by the EC through the Contract of Association. More details are given in the detailed Annual reports for years from 2007 to 2013.

Before its accession to the European Union in May 2004, Lithuania was not associated with EURATOM. However, since then Lithuanian researchers have been active, and in 2005 they managed to succeed in three EFDA technology calls for proposals; as a result, they participated in fusion research by means of cost-sharing actions. These involve a safety study, the design and analysis of the inboard rail of the ITER divertor cassette, and the characterisation of W-coatings for fusion applications. Tasks of physics – calculation of the cross-sections of atomic processes useful for plasma diagnostics – were delayed until the start of the new Association.

Participants of the kick-off meeting in Kaunas, Lithuania on November 15, 2006

After negotiations, which started in 2006, between the European Commission and the partners in Lithuania, a Contract of Association was signed. The new Association is comprised of the Lithuanian Energy Institute (LEI) in Kaunas, Lithuania and the Institute of Theoretical Physics and Astronomy of Vilnius University (VU ITPA).

The kick-off meeting of EURATOM/LEI association took place at Lithuanian Energy Institute in Kaunas, Lithuania on November 15, 2006. The representatives of the European Commission Y. Capouet, M. Pipeleers, B. Green, and S. J. Booth participated at the kick-off meeting. The Director Prof. E. Ušpuras signed the Contract of Association, and he was designated as the Head of Research Unit. The Contract of Association came into force on January 1, 2007, and Lithuania became a new member of the EURATOM Fusion programme.

In 2007, the co-operation of EURATOM/LEI with EURATOM/IPP was initiated in order to take part in the design of fusion facility W7-X, which is being constructed at Max-Planck-Institut für Plasmaphysik in Greifswald, Germany. This co-operation was very successful and continued through 2007–2013 by getting more active in all fields.

During 2007–2013, VU ITPA was implementing activities in the field of theoretical studies of tungsten atoms ionisation. Tungsten as a heat-resistant material is planned to be used at ITER. Using tungsten in some parts of the tokamak may solve the tritium retention problem. On the other hand, tungsten atoms can detach from the inner walls of the fusion reactor, penetrate into the plasma and be ionised to very high degrees. Various tungsten ions will irradiate strongly thus cooling

On December 4-5, 2007 representatives of EC, Mr. S. Booth and Mr. M. Pipeleers visited EURATOM/LEI organizations VU ITPA and LEI to observe the situation and clarify the administrative issues

the plasma. Our association performed theoretical studies of the spectroscopic characteristics of highly charged tungsten atoms having open d and f-shells accounting for relativistic and correlation effects. These results could contribute to the development of plasma diagnostic techniques in the future.

In 2010 in Lithuania the Research Centre of Future Energy Technologies was established within the Valley "Santaka". The computer cluster was installed at LEI in the frames of valley "Santaka" and was used for fusion application especially for structural analysis.

Starting from 2012, LEI started participation in the Power Plant Physics and Technology Implementing Agreement (PPP&T IA) under EFDA. The fields of activities are Reliability, Availability, Maintainability and Inspectability (RAMI) analysis, safety analysis and neutron transport calculations.

For several years LEI and VU ITPA received financial support from the Agency for Science, Innovation and Technology (Lithuania) for the implementation of the EURATOM/LEI project.

LEI became the member of FUSENET association in 2014.

1 SCIENTIFIC ACTIVITIES

1.1 Activities in 2007

In 2007 the co-operation between LEI and IPP-Greifswald was established. It was agreed that LEI experts perform safety assessment of the loss-of-coolant accident for W7-X in case of 40 mm pipe rupture in Plasma Vessel in during "baking" mode of operation. The data about the divertor cooling system and the Plasma Vessel geometry was collected and detailed models were developed. The thermal-hydraulic analysis of W7-X cooling system was performed to some extent.

The possibility to apply the "Leak Before Break" (LBB) concept for pipes of W7-X was investigated. LBB is a complex analysis, which demonstrates the safety function when the initiated surface crack grows to a through-wall crack, and some amount of coolant will flow away through this crack; this leak during definite time can be detected by leak monitoring system, and the through-wall crack will remain stable under all predictable loading conditions. The consequences of such accidents could be tremendous and are difficult to predict. One of the means to demonstrate the absence of undesirable guillotine rupture of pipes is the implementation of the LBB concept. The application of the LBB concept and installation of leak monitoring systems is a safety improvement argument.

VU ITPA investigated the topics related with Energy spectra of tungsten W^{29+} – W^{34+} ions, interpretation of the intensive emission of tungsten ions at about 5 nm, and relativistic electron-ion scattering calculation.

1.2 Activities in 2008

In 2008 LEI performed the analysis of 40 mm pipe rupture during "baking" mode operation. This analysis was performed using the detailed model of the divertor cooling system, developed in 2007 and considered comments of IPP-Greifswald comments. The LBB analysis was performed in detail as well. Results of the LBB analysis were discussed with the experts of IPP-Greifswald.

VU ITPA continued theoretical investigation of energy spectra and relative intensities of radiation of tungsten ions:

- Development and usage of efficient computer codes for accurate calculations of spectral properties of W ions;

- Electron-impact double ionization of tungsten atoms and ions at low ionization stages;
- Theoretical investigation of the quenching of intensity in the 4d -4p and 4f - 4p transitions due to configuration mixing in the ions with 4d open shell;
- Relativistic methods for electron-ion scattering calculation;
- Properties of Auger electrons following excitation of polarized atoms by polarized electrons.

As well in 2008 VU ITPA implemented activities according to JET order (JW8-O-LEI-01C) and JET notification (JW08-N-LEI-01).

1.3 Activities in 2009

In 2009 LEI continued activities related with accident analysis and evaluation of consequences for W7-X. A detailed analysis of whether the water hammer phenomenon could be expected in the divertor cooling circuit in case of LOCA was performed, and the conditions how to avoid water hammer occurrence in the piping were identified.

The performed analysis showed that the target module 1H, according the material properties, complies with the LBB requirements. Performed LBB analysis showed that a small leak will be observed in case of a small crack size, and the guillotine rupture of the pipe cannot be expected.

The models for analysis of the welds between Plasma Vessel and cryostat for the ports AEU20 and AEU30 were developed and prepared for detailed analysis.

VU ITPA continued theoretical investigations of the atomic parameters for spectroscopic plasma diagnostics:

- New form of universal potential designed to solve quasirelativistic equations;
- Application of new quasirelativistic approach for investigation of highly-charged tungsten ions;
- Application of the quasirelativistic approach for investigation of W II ion;
- Investigation of Auger cascades and relaxation effects following the production of a vacancy by electron impact in the tungsten W^{+}, W^{3+} and W^{5+} ions;
- Relativistic electron-ion scattering calculation;
- Calculation of collision strengths for the W^{45+} ions using relativistic R-matrix code;

- Theoretical study of magnetic dipole transitions using Dirac-Fock approach;
- Properties of Auger electrons following excitation of polarized atoms by polarized electrons.

1.4 Activities in 2010

The largest part of our activities is related to Wendelstein 7-X programme implemented by Max-Planck-Institut für Plasmaphysik (IPP) in Germany. In 2010 our association performed assessment of the W7-X target cooling system and structural integrity analysis of the port welds.

Assessment of W7-X cooling system performance was carried out using computer codes RELAP5 and COCOSYS and integral computer code ASTEC. Detailed thermal-hydraulic model was developed to represent the complicated cooling system of W7-X and to simulate the accident scenario "rupture of 40 mm pipe inside Plasma Vessel". COCOSYS code was used for detailed analysis of Plasma Vessel response, while ASTEC code was used to perform integral analysis of the entire accident sequence in the cooling circuit and Plasma Vessel. Performed calculations gave the coolant leak rate and pressurization of W7-X Plasma Vessel, which were used to estimate the reliability of Plasma Vessel protection system. The performed analysis showed that planned design of Plasma Vessel protection system ensures pressures below design limits.

Structural integrity analysis of W7-X port welds was performed for the following ports/port combinations:

1. Welding connection between the port AEQ20 and the PV shell.
2. Welding connection between the port AEU30 and the PV shell.
3. Welding connection between the port AEK20 and the PV shell.

The structural integrity analysis of these port welds between PV and the ports in W7-X cryostat system was performed using finite element method. The models of port welds were prepared using software SolidWorks and Brigade/Plus. A validated Finite Element code.

1.5 Activities in 2011

The largest part of our activities is related to Wendelstein 7-X programme implemented by Max-Planck-Institut für Plasmaphysik (IPP) in Germany. In 2011 our association performed an assessment of the W7-X Plasma Vessel venting system capacity, a structural integrity analysis of the port welds, and an assessment of Divertor cooling circuit availability as a part of probabilistic risk analysis.

Assessment of W7-X Plasma Vessel venting system capacity was performed using computer codes RELAP5 and COCOSYS. RELAP5 was used to determine the

mass and energy flow rates through the ruptured pipe and gas flows through the venting system. A detailed thermal-hydraulic model was developed to represent the complicated cooling system of W7-X. COCOSYS code was used for a detailed analysis of Plasma Vessel venting system. Different scenarios were investigated to estimate the acceptance of the design of the venting system. When the results of RELAP5 and COCOSYS calculations were compared, a significant difference in timing of safety valve opening was observed and an investigation was performed to identify the reasons for such difference. The performed analysis showed that the current design of Plasma Vessel venting system ensures pressures below design limits.

The port welds between the Plasma Vessel and the ports in W7-X cryostat system were investigated. The structural integrity analysis of the welding connections was performed for the following ports/port combinations:

- Welding connection between the port AEQ20 and the PV shell with a 1 mm gap.
- Welding connection between the port AEU30 and the PV shell with a 1 mm and 6 mm gap.
- Welding connection between the port AEK20 and the PV shell with a 1 mm gap.

These ports were modelled using the FEM technique as 3D bodies together with the regions of the PV shell around the ports and the welding seam. The main objective of the analysis was to calculate the load scaling factors for all considered ports. For the geometrical modelling, CAD program SolidWorks was applied. Structural analysis of the ports was performed using ABAQUS code.

According to stress analysis results, it was received that the stresses in port and vessel are below the yield strength. The stresses in welded zone of port and PV in nodes of some elements exceed the yield strength, but the mean value of stresses is below the yield strength. The influence of these elements to stress condition of the entire structure is minor. According to limit analysis results, the fact that displacement of the point where loads are applied starts to increase very rapidly was not detected. The limit analysis showed positive results of the welding between Plasma Vessel and ports, which means that the stability of the welding between Plasma Vessel and considered ports will be sustained at used loading for the analysis.

For the first time, the W7-X probabilistic risk analysis was performed to estimate the Divertor cooling circuit ACK10 availability and recommend measures to increase availability of this circuit. RiskSpectrum ® PSA Professional developed by Relcon Scandpower AB (Sweden) was used. The performed analysis showed that unavailability of the ACK10 is 18.8 % of the operational campaign. The main impact to unavailability comes from the operation regime of the cooling pumps, which leads to high cyclic load and high failure probability to the secondary pump and its regulating valve. These components bring correspondingly 51 % and 35 %

to the total unavailability. Four options for increasing ACK10 availability were analysed, and it was determined that changing pumps operation mode does not increase overall reliability of the system. Installation of the 3rd redundant pump and keeping a set of necessary spare parts are similar from the risk decrease perspective, but from the cost effectiveness point of view, keeping spare parts could be a preferable option. Preventive maintenance of the pumps gives the least decrease of risk from the considered options.

Tungsten as a heat-resistant material is planned to be used at ITER. Using tungsten in some parts of the tokamak may solve the tritium retention problem. On the other hand, tungsten atoms can detach from the inner walls of the fusion reactor, penetrate into the plasma and be ionised to very high degrees. Various tungsten ions will irradiate strongly thus cooling the plasma. Our association performed theoretical studies of the spectroscopic characteristics of highly charged tungsten atoms having open d and f-shells accounting for relativistic and correlation effects. These results could contribute to the development of plasma diagnostic techniques in the future.

1.6 Activities in 2012

The largest part of our activities is related to Wendelstein 7-X programme implemented by Max-Planck-Institut für Plasmaphysik (IPP) in Germany. In 2012 our association performed the assessment of the water hammer effect during normal operation and a detailed assessment of W7-X Plasma Vessel venting system capacity, the limit load analysis of the port welds, the assessment of the pipe whip possibility in case of pipe rupture as well as the assessment of cooling circuit in case of loss of off-site power.

The assessment of W7-X Plasma Vessel venting system capacity was performed using computer codes RELAP5 and COCOSYS. RELAP5 was used to determine the mass and energy flow rates through the ruptured pipe and gas flows through the venting system. A detailed thermal-hydraulic model was developed to represent the complicated cooling system of W7-X. COCOSYS code was used for a detailed analysis of Plasma Vessel venting system. Different scenarios were investigated to estimate the acceptance of the design of the venting system. The performed analysis showed that the current design of Plasma Vessel venting system ensures pressures below design limits.

The port welds between the Plasma Vessel and the ports in W7-X cryostat system were investigated, and analysis was performed to define the limit load for welding connection between the port AEU30 and the PV shell with a 1 mm and 6 mm gap. The welding efficiency for analysis was assumed 0.7 and 0.85. The received results showed that limit loads are significantly higher than expected loads during operation, thus the integrity of the welding will be ensured.

Probabilistic analysis of freezing of W7-X water cooling circuit ABK10, which is located close to the cold cryostat, in case of loss of offsite power supply was performed. Several accident scenarios that could lead to circuit freezing were investigated: 1) failure of Emergency Diesel Generator and switch to alternative power source, 2) failure to restart circulation and 3) failure to drain water. The results show a rather high safety barrier against the initiating event; however, several recommendations were given to increase reliability of the system.

In 2012 the first **JET Notification** of LEI was signed to perform calculations of dose rates from shields in support of JET neutron detector calibration. MCNP code was used for the analysis. The results were discussed during semiannual monitoring meetings at CCFE (Culham, UK). At present, the final report is being finalised after the comments, raised during the meeting in Culham in December 2012.

Tungsten as a heat-resistant material is planned to be used at ITER. Using tungsten in some parts of the tokamak may solve the tritium retention problem. On the other hand, tungsten atoms can detach from the inner walls of the fusion reactor, penetrate into the plasma and be ionised to very high degrees. Various tungsten ions will irradiate strongly thus cooling the plasma. Our association performed theoretical studies of the spectroscopic characteristics of highly charged tungsten atoms having open d and f-shells accounting for relativistic and correlation effects. These results could contribute to the development of plasma diagnostic techniques in the future.

In 2012 our association continued activities in the frames of EFDA WP 2012 in the following tasks:

- Design Tools and Methodologies WP12-DTM02 “Reliability Growth”. LEI was involved in:
  - o WP12-DTM-02-T01: Expected initial availability and availability growth of the DEMO based on historical data
  - o WP12-DTM-02-T05: Evaluation of RAMI Tools for DEMO.

1.7 Activities in 2013

The largest part of our activities is related to W7-X programme implemented by Max-Planck-Institut für Plasmaphysik in Germany. In 2013 our association performed assessment of LOCA impact on W7-X Plasma Vessel internal structures, assessment of limit load analysis of the port welds as well as assessment of cooling circuit in case of loss of off-site power.

Assessment of W7-X Plasma Vessel venting system capacity was performed using computer codes RELAP5 and COCOSYS. RELAP5 was used to determine the mass and energy flow rates through the ruptured pipe and gas flows through the venting system. Detailed thermal-hydraulic model was developed to represent the complicated cooling system of W7-X. COCOSYS code was used for detailed

analysis of Plasma Vessel.

The port welds between the Plasma Vessel and the ports in W7-X cryostat system were investigated, and the analysis was performed to define the limit load for welding connection between the port AEK20 and the PV shell with a 1 mm gap. The welding efficiency for analysis was assumed 0.7 and 0.85. The received results showed that limit loads were significantly higher than expected loads during operation, thus the integrity of the welding will be ensured.

The reliability analysis of the W7-X plasma vessel and ports cooling circuit ABK10 and the divertor target cooling circuit ACK10 were performed. The total unavailability and its main contributors are identified for "baking" and plasma operation modes.

In 2013 LEI participated in JET task JW13-FT-5.54 Activation cross sections for DD, DT and TT neutrons from JET plasmas. The goals of the present task were the following: 1) Assess and update the activation cross sections used in JET neutron diagnostics both at 2.5 and 14 MeV neutron energy in view of the DT campaign, with particular regard to the related uncertainty in typical JET neutron spectra, and 2) Investigate suitable activation cross sections for measuring the TT neutron spectrum. Assess the related uncertainty.

In 2013 our association continued activities in the frames of EFDA WP 2013 in the following tasks:

- Design Tools and Methodologies WP13-DTM-02 "Reliability, Availability, Maintainability & Inspectability (RAMI)". LEI was involved in:
  - WP13-DTM-02-T02: Method to evaluate and integrate diverse RAMI input data;
  - WP13-DTM-02-T04: Analysis of the DEMO Availability Requirement.
- System Codes WP13-SYS-02 System Level Analysis:
  - WP13-SYS-02-T08: Activation and radiation dose map calculation.
- System Codes WP13-SYS-04 Safety:
  - WP13-SYS-04-T05: Review of modelling codes and identification of development needs.

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2 OTHER ACTIVITIES

2.1 Collaboration of VU ITPA with ADAS and JET

The contacts established in 2008 with Prof. H. Summers who is the leader of the ADAS (Atomic Data Analysis System) in JET were continued in 2009. Dr. V. Jonauskas has calculated ion yield data after processes of Auger cascade in tungsten ions W^{2+}, W^{4+}, W^{6+} and discussed the possibilities to use these data for the JET plasma diagnostics. It was decided that shake-off processes could be important for the double ionization rates in Auger cascade calculations and plasma diagnostics.

Dr. R. Kisielius carried out the installation, porting and testing of the Flexible Atomic Code (FAC) program package on a JET computer cluster in 2008. In 2009, this code was used for the calculations of the energy levels, Auger transition rates and dielectronic recombination rates for the autoionizing states of W^{13+}, W^{14+}, W^{7+}, and W^{8+}. The results were discussed with ADAS group members.

2.2 Agreement between University of Strathclyde and Vilnius University

In 2011 VU TFAI worked under subcontract agreement between University of Strathclyde and Vilnius University. The tasks were the following:

- A benchmark study for W I, W II, and W III using the Bogdanovich's quasi-relativisitic (QRHF) approach. The structure and transition probability studies will be extended to implement plane-wave Born cross sections, so that delivery can be in the form of ADAS adf04 datasets. Professor N. R. Badnell from ADAS-EU will collaborate with Professor P. Bogdanovich and his co-workers and provide support procedures and sub-routines, so that the link from the structure to the plane-wave Born can be made.
- A benchmark study in Dirac-Fock approximation of a selected lanthanide-like ion in a low charge state (~6-12). The study is designed to assess the possibility of a more extensive use of such heavy elements as markers (observed in low ionisation stages in divertor regimes) and edge transport studies and cross-reference other approximate studies of low charge state tungsten ions. Suitable ions would be W^{+8} (Dy-like).

- Multiple electron ionisation rate coefficients, with special emphasis on 4d, 4f and 5d, 5f open-shell systems. The study should be based on contiguous sets of iso-nuclear ions of selected elements, from which approximate general prescriptions can be inferred. This will include design of an extension of ADAS data formats adf23 and adf07.
- Exploitation of ITPA special studies of key complex ion configuration interactions (such as symmetric exchanger of symmetry) by inclusion in ADAS data format adf54, tuned to primary resonance line spectroscopy, with special emphasis on 4d, 4f and 5d, 5f open-shell systems.

All tasks were completed, and the computer codes were developed. They enabled us to calculate successfully the electron-impact excitation in plane-wave Born approximation for H, He, Li and Fe^{21+} by using the data of the energy level spectra obtained in the quasirelativistic approach. This approach was developed in the Department of Atomic Theory of Institute of Theoretical Physics and Astronomy, Vilnius University. Several exploratory calculations were performed for the tungsten W^{2+} ion. The peculiarities of W^{8+} were investigated taking into account both relativistic and correlation effects. Double ionisation rate coefficients for W^{3+}, W^{4+} and W^{5+} ions were calculated. The energy level spectra, cross sections of single ionization and excitation by electron impact as well as rates of Auger transitions have been obtained. They demonstrated that the direct double ionization might play the main role in producing doubly-ionized ions. The configuration interaction (CI) effects in the W^{+13} and W^{20+} ions by employing the extended basis of interacting configurations were studied. The data were used for the simulation of the spectra emitted from EBIT plasma. Their applicability for the simulation of JET plasma was also discussed.

In 2012 in collaboration with Strathclyde University researchers working on ADAS-EU project, the investigations of W ions were carried out by VU ITPA scientists. The theoretical study in quairelativistic approximation with correlation effects included in multiconfiguration approximation with transformed radial orbitals base was performed not only for four low-ionization tungsten ions (W^{2+} – W^{5+}), but also for adjoined element ions of hafnium (Hf – Hf^{3+}), tantalum (Ta^{1+} – Ta^{4+}) and rhenium (Re^{3+} – Re^{6+}).

All investigated ions have open 5d-shell in their ground configurations. It is well known that 5d-electrons have energy values close to those of 6s-electrons for neutral atoms and first ions. Since these electrons (5d and 6s) have the same parity, a strong mixing of the $5d^N$, $5d^{N-1}6s$ and $5d^{N-2}6s^2$ takes place. Therefore, the energy levels of these configurations cannot be investigated separately. Configuration mixing effects lead to a situation that the analysis of eigen-functions sometimes cannot provide a definitive assignment of particular energy level to any single above-mentioned configuration. Similar situation occurs for the excited odd configurations of these ions.

Keeping that in mind, we have chosen such an approach. The energy levels of three even-parity configurations $5d^N + 5d^{N-1}6s + 5d^{N-2}6s^2$ (N = 1,2,3,4) were

computed simultaneously. The most important admixed configurations were selected for each of these configurations. The same approach was applied for determining energy levels of three odd-parity configurations $5d^{N-1}\,6p + 5d^{N-2}6s6p + 5d^{N-3}6s^2 6p$ ($N = 1,2,3,4$). For adjustment of admixed configurations, the basis of transformed radial orbitals with principal quantum number n in range from 7 to 9 and all possible values of orbital quantum number ℓ was established. The selection criteria for the admixed configurations had a range from 10^{-5} to 10^{-7}. A comparatively large value (10^{-5}) for selection criteria was chosen for the configurations with $N = 4$. Nevertheless, the main correlation effects were taken into account. A simultaneous computing of three strongly-mixing configurations enabled inclusion of 3-electron and 4-electron correlation effects. The increase of value for selection criteria was caused by fact that configuration groups with $N = 4$ have huge number of *LS*-terms; therefore, it was not possible to extend configuration basis due to limited resources of our computer clusters. Even the use of such a restricted configuration basis would consume some 400-500 CPU hours to complete calculations for one ion.

We have determined eigenvalues and eigenfunctions for the even-parity configurations $5d^N + 5d^{N-1}6s + 5d^{N-2}6s^2$ ($N = 1,2,3,4$) and the odd-parity configurations $5d^{N-1}\,6p + 5d^{N-2}6s6p + 5d^{N-3}6s^2 6p$ ($N = 1,2,3,4$) in our calculations. Applying these results, we have determined the first Born - electron-impact excitation cross sections and collision strengths for the transitions among levels of even-parity configurations and for the transitions from the levels of even-parity configurations to the levels of odd-parity configurations. Our data were transferred to the Strathclyde University collaborators.

3 MOBILITY PROGRAM

In 2007 Dr. L. Pranevičius took part in the 8th meeting of the ITPA Div-SOL TG, which was held on May 7-10, 2007 in Garching, Germany and in the Task Force PWI 2007 General meeting, which was held on October 27–November 2, 2007 in Madrid, Spain.

In September 2007 Dr. E. Urbonavičius, Dr. G. Dundulis and Prof. J. Augutis (LEI) visited Max-Planck-Institut für Plasmaphysik in Greifswald (Germany) to discuss the fields and the scope of possible co-operation. At the meeting it was decided to concentrate activities in the following fields:

- Static and Dynamic Structural integrity analysis of Complex Components of the W7-X device and its main components during normal operation and failure events;

LEI representatives G. Dundulis (left) and T. Kaliatka (center) discuss details of the W7-X device with the IPP representative D. Naujoks (right)

- Thermal-hydraulic analysis during normal operation and failure events;
- Systems safety analysis (incl. complex systems as well as passive and active safety components and their installation).

In later years up to 2013, the co-operation with IPP-Greifswald followed these main topics. Active cooperation and annual meetings at IPP-Greifswald gave possibility for LEI experts to observe construction of W7-X up to closure of the cryostat. These were valuable meetings with informative discussion on the achieved results. During visits to IPP-Greifswald, the opportunity was taken to meet with different specialists, e.g. Mr. A. Tereshchenko, Mr. J. Fullinger, Mr. V. Bykov from structural analysis department.

LEI representative E. Urbonavičius (left) discuss obtained calculation results with IPP representative D. Naujoks (right)

During the year 2011, Mr. R. Voronov had three long-term secondments to IPP – 30 days duration each. During these visits, he collected data, developed models, and performed the System Reliability Analysis. The methods similar to ITER RAMI (Reliability, Availability Maintainability Inspectability) were applied for this analysis. Divertor Target Cooling Circuit ACK10 was chosen for investigation.

Mr. Naujoks and Mr. S. Bosch of IPP-Greifswald followed the progress and actively participated in discussions.

In 2008 under the topic "Power and particle exhaust and plasma-wall interaction," two missions of VU ITPA experts to UKAEA Culham were organised. Dr. V. Jonauskas and Dr. R. Kisielius visited Culham to work on calculation of tungsten ions ionisation and magnetic dipole transitions in highly charged

tungsten ions from W^{29+} to W^{37+}. During the mission, it was decided to extend ADAS database by double ionization rates from Auger cascade calculations in tungsten ions. The Flexible Atomic Code program package has been installed on JET computer cluster. The initial calculation of the energy levels of W^{13+} and W^{14+} ions was performed, and the results were presented.

Mr. E. Urbonavičius participated in Information Session on the New Mobility Agreement, which was held in Brussels on October 19, 2009. This meting was not originally included in the mobility plan. At the meeting the presentations on the new mobility legal, organisational and financial aspects were given by the representatives of the European Commission. The participants were involved in discussions on the implementation of the new mobility agreement. The information received at the meeting is valuable and will be used in our association EURATOM/LEI.

Mr. R. Urbonas, Mr. R. Alzbutas and Mr. E. Urbonavičius took part in the EFDA Public Information Network activities and several years participated in the Annual Meetings, which were held in Risø, Roskilde (Denmark) in 2010, in Greifswald (Germany) in June 2011, and in Culham (UK) in June 2012.

In 2012 Mr. G. Stankūnas visited CCFE and together with Dr. S. Conroy and Dr. B. Syme discussed the planned cooperation activities in 2012. Later in December 2012 Mr. G. Stankūnas visited CCFE to discuss the results of performed calculations. He presented neutron calculations that have been carried out to evaluate the dose rate leakage from the shields, which contain the neutron source.

Mr. R. Alzbutas and Mr. R. Voronov participated in kick-off meetings of EFDA PPP&T agreement WP12-DTM02 that were held on 17-19 April 2012 and in the final meetings of this task that were held on 11-13 December 2012. Both meetings were held at IPP-Garching, Germany. At the kick-off meeting detailed plans for implementation of the tasks were agreed upon, while the final meetings were held to discuss the achieved results.

Mr. G. Stankūnas participated at EFDA PPP&T Task planning meetings on WP13-SYS02 and WP13-SYS04 that were held on 7-8 November 2012. During the meetings the detailed work programs for 2013 were discussed with the meeting participants.

Mr. G. Stankūnas visited CSU-Garching on 08/04/2013–10/04/2013 to participate at the kick-off meeting of WP13-SYS02 “System level analysis”. At the meeting detailed activities were discussed among the participants. Three associations involved were in WP13-SYS02-T08: CIEMAT, KIT, and LEI. The aim of the task was to use MCNP coupled with FISPACT/EAF to calculate the activation and decay heat production of the in-vessel components.

Mr. R. Alzbutas and Mr. T. Iešmantas participated at the kick-off meeting of task area WP13-DTM02 “DEMO RAMI tools & methodologies”, which was held at CSU-Garching during 11/04/2013–13/04/2013. Mr. R. Alzbutas discussed activities

in WP13-DTM02-T04 "Analysis of the DEMO Availability Requirement", and Mr. T. Iešmantas discussed activities in WP13-DTM02-T02 "Method to evaluate and integrate diverse RAMI input data".

Mr. E. Urbonavičius participated at the interim meeting of WP13-SYS04 "Safety", which was held in the premises of CSU-Garching during 23/09/2013–25/09/2013. The results already achieved and plans for completion of the tasks were discussed and agreed upon among the participants. LEI participated in activities of WP12-SYS04-T05 "Report on tools for safety studies", which was coordinated by ENEA. At the final meeting, Mr. E. Urbonavičius made a presentation on WP12-SYS04-T05 draft final report.

Mr. E. Urbonavičius and Mr. G. Stankūnas participated at the EFDA information meeting, which was held at CSU-Garching during 28/10/2013–31/10/2013. At the EFDA information meeting, the announced Calls for Participation in work plan 2014-2018 tasks were discussed among the participants. At the meeting the information about the new rules for participation in fusion research activities was presented by the project coordinators.

Mr. G. Stankūnas visited CCFE during 04/11/2013–06/11/2013 to participate at the EFDA information meeting. Announced at the meeting Calls for Participation in work plan 2014-2018 tasks were discussed among the participants. At the meeting the information about the new rules for participation in fusion research activities was presented by the project coordinators.

Mr. G. Stankūnas visited CCFE during 11/06/2013–14/06/2013 in the frames of Fusion technology task force (TF-FT) to participate in the EFDA JET monitoring meeting. Together with dr. Paola Batistoni the activities in 2013 were discussed, and semi-annual meeting presentation was delivered. Some issues regarding availability of final neutron spectra were identified.

4 PUBLIC INFORMATION

All activities which were organised in LEI are mentioned (with photos, presentations) on the web-site of LEI http://www.lei.lt in section "News" -> "News archive" (in both English and Lithuanian versions). The information on FUSION and EURATOM-LEI activities is available on the web-site of LEI http://www.lei.lt in section "International projects" -> "EURATOM-LEI".

The information related with FUSION energy perspectives, last achievements in ITER development, and other Fusion research fields is continuously distributed among universities, R&D institutions, schools:

- Occasionally, school teachers (physics, chemistry…) from various regions of Lithuania visit the Institute. In addition, they receive information and brochures on fusion. Information is spread via personal contacts as well.
- Through our partner Vytautas Magnus University, which is located in Kaunas, Lithuania, the information is spread to schools when university looks for students of physics studies.
- In 2009, 2010 and 2011. FP7 project "Researchers night". Distribution of information and discussions on FUSION to students.
- March 19, 2011. Competition "EnIdėja – Green Energy Idea 2011" at Vytautas Magnus University, Kaunas Lithuania. Distribution of information on FUSION to graduating students of Secondary schools. (http://www.lei.lt/main.php?m=466&l=1414&k=1)

Three lectures "We can produce energy as stars do it" have been presented by O. Rancova to the general public within the framework of European Researchers Night on September 26, 2008. ITER project and participation of Lithuanian scientists in it have been introduced by the lectures.

Popular lectures by **Olga Rancova** "The energy will be produced like in stars":

1. Festival of Science "Spaceship-Earth", Kaunas Jesuit Gymnasium, 16/09/2009;
2. Lithuanian Museum of Energetics, 21/04/2009;
3. Akmenės Gymnasium and 4 secondary schools, 22/04/2009;
4. Vilnius Sofija Kovalevskaja Secondary school, 28/04/2009;

5. Upynos community (Šilalės district) 23/05/2009;
6. Estate Kurtuvėnai (Telšiai district) 23/05/2009;
7. Science Festival "Star Nights", Astronomical Observatory of the VU Institute of Theoretical Physics and Astronomy, 17/05/2009.

Exhibitions and communication to public

The information related with FUSION energy perspectives, last achievements in ITER development and other Fusion research fields is continuously distributed among universities, R&D institutions, schools:

- Presentation in Lithuanian Academy of Sciences by Algirdas Kaliatka on 11 December 2012 on fusion in a discussion "Energy issues and future energy" (http://naujienos.vu.lt/ivykiai/anonsai/25828-diskusija-fizikins-energetikos-problemos-ir-ateities-energetika). Information about this presentation was published by Ugnė Karaliūnaitė and Vaidas Neverauskas in most popular news portal DELFI: archive http://verslas.delfi.lt/archive/article.php?id=60216115

Annual events:

- International Conference of Young Scientists on Energy Issues (CYSENI) (www.cyseni.com) organised by the Lithuanian Energy Institute includes topic on fusion power. A keynote lecture on fusion power was given at one of the conferences.
- Carrier days at Kaunas University of Technology are organised annually, and we disseminate material on fusion power and attract students to devote their scientific careers to this important topic.
- Open days of Lithuanian Energy Institute. Distribution of information and discussions on FUSION with students (http://www.lei.lt/main.php?m=466&l=1446&k=1)
- International annual expositions "Kaunas 2008" – "Kaunas 2013", Kaunas, Lithuania. Distribution of information on FUSION to public.

Public paper in news portal

- A public paper "The part of the most extreme experiment for Lithuanian scientists" http://www.delfi.lt/mokslas/mokslas/lietuvos-mokslininkams-patiketa-ekstremaliausio-eksperimento-zemeje-dalis.d?id=64407004#iXzz2xc3iHW6X (in Lithuanian) was prepared by Chief Specialist in Public Relations of the Lithuanian Academy of Sciences R. Maskoliūnas who was consulted by P. Bogdanovich of Vilnius University.

Public paper in popular science journals

1. Pranevičius L., Integration of Lithuanian science to the European Research on FUSION energy, Lithuanian Journal "Mokslas ir gyvenimas" ("Science and Life"), No. 6, 2007.
2. Kriščiukaitienė G., "FUSION energy – from dreams to reality, Lithuanian popular science journal "Mokslas ir technika" ("Science and Technology") ISSN 0134-3165, 2007, No. 5, p. 34.
3. Article "Renewable energy is more than brain" in science popularisation magazine "Science and Life", 2009 No. 4 p.5-7, 40-41 by Prof. Jonas Grigas. A chapter (p. 41) is devoted to the fusion energy.

Outreach and education

- The Club of young power specialists established by the students of Vilnius University are organising lectures about different energy issues. A. Kupliauskienė of VU ITPA gave a lecture "The perspectives of thermonuclear energy" at the meeting of this club at Vilnius University (Lithuania) in November 2013.

Appearance in the media

- P. Bogdanovich gave an interview about nuclear fusion and ITER project for TV show "Science express" at the national Lithuanian TV. The recorded interview is available at http://www.delfi.lt/video/mokslas-ir-gamta/mokslo-expresas/mokslo-expresas-gilyn-i-atoma.d?id=64276878 (in Lithuanian). This interview is also available at http://www.youtube.com/watch?v=pCHWmudVhIE.

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