4 ITER and Wendelstein 7-X

Polish contribution in the Wendelstein 7-X programme is considered to play a very important role in the integration of all Polish parties, that form our Association. Polish involvement in the W7-X programme is quite extended, ranging from cooperation on device assembly and development of NBI system through development of several diagnostics (X-ray PHA, C/O monitor, neutron and microwave diagnostics) to structural mechanical calculations and neutron MCNP calculations.

- Contribution to the project W7-X

  - Contribution in preparation of W7-X assembly process: including work organization, documentation of assembly process, modifications of equipment and training of technicians. Assembly of bus bars powering superconducting coils on the stellarator modules. Design of tooling necessary during modules assembly
  - Spectrometry of soft X-ray emission from W7-X stellarator with the use of PHA and MFS diagnostics
  - C-, O- monitor system for W7-X
  - Development and application of neutron diagnostics based on activation method for magnetic confinement devices (W7-X)
  - Detection of the delayed neutrons from activation of fissionable materials in the neutron field at fusion-plasma devices
  - Numerical analysis and evaluation of the structural mechanical behaviour of magnet system components of W7-X

The participation of our Association in tasks given by ITER IO and F4E are two former Article 5.1b, which were completed successfully last year. Wroclaw University of Technology (WrUT) has been continuing the contract related to Review of complex cryolines – support to India DA. WrUT has also taken up a new task connected with Risk Analysis of ITER Cryogenic System. AGH University of Science and Technology received grants from F4E in relation with Nuclear Data studies/experiments in support of TBM activities, in which the following tasks are included: the first - Developing innovative 3H measurement procedure directly in LiPb and the second Conceptual design of a direct TPR measurement system without Tritium escape or with Tritium escape control.

- Contribution to ITER

  - Nuclear Data studies/experiments in support of TBM activities (F4E grant)
    Including:
    - Development of an innovative 3H measurement procedure directly in LiPb, HCLL TBM mock-up material
    - HCLL/HCPB: Measurement of the ^{203}Hg production in LiPb material through ^{206}Pb(n,a) and ^{207}Pb(n,na') reactions
    - Conceptual design of a direct TPR measurement system without Tritium escape or with Tritium escape control
    - HCLL: Post-analysis of the whole experiment including sensitivity and uncertainty analysis
  - Review of cryogenic distribution components (cryolines and cold boxes) preliminary design – support to India DA (IO Contract)
  - Risk Analysis of ITER Cryogenic System (IO Contract)

4.1 Contribution to the W7-X project

Contribution in preparation of W7-X assembly process: including work organization, documentation of assembly process, modifications of equipment and training of technicians. Assembly of bus bars powering superconducting coils on the stellarator modules. Design of tooling necessary during modules assembly
(At no cost for EURATOM Contract of Association except Mobility)

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The main features of the stellarator and specific work packages of the IFJ PAN team were described in the Annual Reports 2008 and 2009. The presented scope of work in 2010 was realized by more than 50 technicians (38 from IFJ PAN and 14 from IPP Greifswald) conducted and supervised by 3 Line Officers (LO) from IFJ PAN. The Bus Bar Assembly Team consisted on the average (at given time) of 20 technicians and 3 Line Officers (LO) working at the same time on W7-X construction.

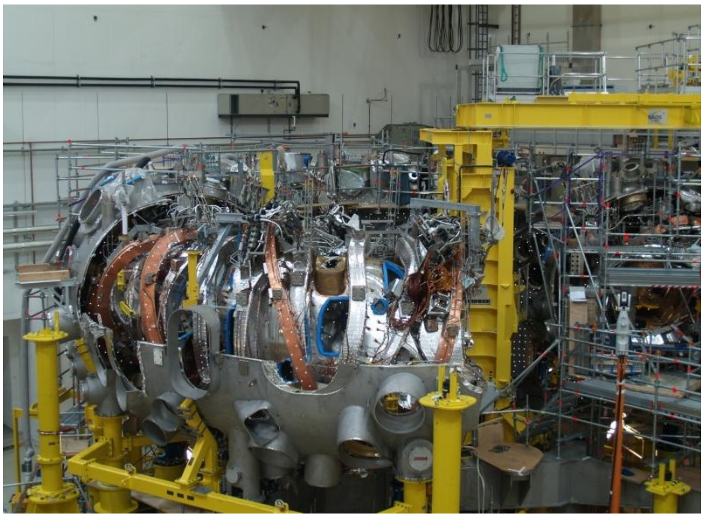
In 2010, the assembly work was continued. Installation of the bus bar systems was completed on the next three modules. Each module required various scope of work to be done. In addition, preparation of 28 bus bars for the final installation on the last module was also finished.

Completion of the bus bar system on module 1
At the beginning of March 2010 the final configuration check on module 1 was done before its moving into the lower shell of the outer vessel. The list of potential collisions had c.a. 70 items. Each of them had to be measured and written into the QAAP (Quality Assurance and Assembly Plan). Several Red Cards (SK-Sperrkarte) indicating the problems were opened due to insufficient distances between bus bars, holders, clamps and other components of the module 1. All nonconformities were corrected, and then approved by Quality Management Team, releasing the module for the moving.

Completion of the bus bar system on module 4
One of the most crucial operations is making the joints. The joint is a connection between the bus-bar and the superconducting coil end. This operation is time consuming and requires highly skilled technicians. In order to finish this task in reasonable time span, this work was performed in shifts (morning shifts also on Saturdays) which implies also shift work for the LOs (Line Officers). Except for welding and scanning these tasks are performed by IFJ PAN technicians, but whole assembly process is supervised by IFJ PAN Line Officers. This requires cooperation with the other departments of the IPP Greifswald. Coordination of different operations is a must, for such a complicated assembly process, in order to keep the time schedule under control.

Completion of the bus bar system on module 2
Final installation of the bus-bars on module 2 was rather delicate operation. Longest bus-bars are about 8 meters long and pre-shaped to the proper form, which is a consequence of the extremely complex layout and geometry of the W7-X stellarator. The handling of the bus-bars is done with help of telescopic poles of few meter lengths, allowing manipulating and placing the bus-bars in the required positions. During the manipulation, helium-filled balloons take over part of the bus bar weight. Due to the bus bar lengths and softness (outer jacket surrounding the superconductor is made of soft aluminium AlMgSi0.5), the bus bars are prone to mechanical damage and deformation of their shape. On average up to 10 people were needed to transport them from the preparation area to the MST and then to place them in previously installed supports. After the bus bars were mounted on module 2 the mechanical assembly of joints started.

The remaining work on the bus bar systems is to complete installation on module 3 in the Mounting Hall. It should be finished by mid 2011. Then, the joints between neighbouring modules at the W7-X ring have to be made, Fig.1. A detail schedule of that work isn't fixed yet, but most likely the work will be completed by end 2012.



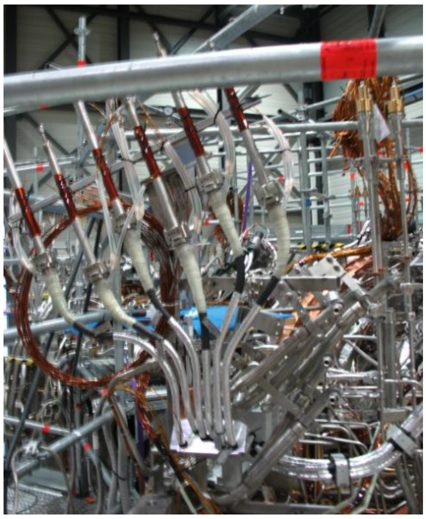


Fig.1 Three modules placed at the W7-X ring (left); ends of the bus bars to be connected (right)

Spectrometry of soft X-ray emission from W7-X stellarator with the use of PHA and MFS diagnostics

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The investigation of the X-ray emission from fusion plasmas has become a standard diagnostic tool used on many different fusion experiments. The measurements of X–ray intensities by using Si–detectors, which are sensitive to the total radiation above a threshold energy determined by thin absorber foils in front of the diodes, yield an excellent spatial and temporal resolution. The determination of the X-ray energy spectrum using pulse height analysis (PHA) systems requires sufficiently long acquisition times resulting in a poor temporal resolution. However, this method is particularly suited for long pulse operation envisaged for W7–X. The multi-foil temperature analysis system (MFS) is the method destined to obtain the shape of the X-ray spectrum from data recorded by the use of different semiconductor detectors. This method is characterized by lower spectral resolution but much faster response in comparison with the PHA system.

Described two spectroscopic systems, PHA and MFS are being designed by IPPLM for measurement of soft X-ray emission from W7-X stellarator, which is now under construction in Greifswald, Germany. The project is carried out within Agreement on Cooperation between Institute of Plasma Physics and Laser Microfusion, Association EURATOM and Max-Planck-Institut für Plasmaphysik – Greifswald, Association EURATOM.

Computer simulations of soft X-ray emission from a tokamak plasma played important role in designing of both diagnostic systems. As a tool for checking the performance of a spectrometry system and optimizing filters and detectors, a special numerical code, named RayX has been developed. Number of simulations have been done and the results allowed to determined the position of the diagnostics components.

The super conducting stellarator W7-X will run pulse of up to 30 min duration with full heating power. Electron Cyclotron Resonance Heating (ECRH) is the main heating method for steady-state operation of the Wendelstein 7-X stellarator in the reactor relevant plasma parameters. A heating power of 10 MW is required to meet the envisaged plasma parameters. A wide spectrum of requirements has to be considered during design and realization of the new X-ray diagnostics. Since ECRH auxiliary heating will be applied in W7-X, different heating scenarios, characterised by widely different electron temperature and density profiles have been taken into account. The RayX code allowed to investigate the influence of a geometrical configuration of the diagnostic systems on the spectra intensity and shape. It also calculated the radiation from plasmas with the use of different pinhole sizes, types of detectors, filters' material and thickness.

Performed simulations and evaluation of the magnetic field effect on the individual elements of the system (e.g. turbomolecular pump) showed that the changeable slits must be placed at a distance of 6.5 m from the plasma center and detectors further 1 m behind them. A preliminary mechanical design of PHA system is presented in figure 1. Details of the chamber (box) which contains three sets of movable slits with piezo drives and pinholes, and three interchangeable filter systems with vacuum manipulator is presented in figure 1b. To collimate and cut off a part of the radiation a plate with three fixed holes has been located in front of the chamber. The proposed PHA diagnostic is intended to provide the spectral energy distribution with energy resolution not worse than 180 eV along a central line of sight. The system will consist of 3 single Silicon Drift Detectors (SDDs). The measurements will be taken along sightlines through the center of the plasma. In the diagnostic all detectors, operated with different filters will be installed on the horizontal port AEK50 on W7-X. Each detector will record an X-ray spectrum in three different energy ranges (energy channels) from 400 eV to 20 keV. This will allow to enhance the sensitivity for particular impurity species and for the investigation of superthermal tails in the spectra. First channel will be equipped with SD3 detector containing polymer window and aluminum light protection, to cover energy range between 250eV-20keV. Second and third channel will be equipped with standard SDD detector with 8µm of Be window, however in the third channel additional thick filter will be used. This will allow to record spectra in the range of 1-20 keV and 7-20keV, respectively. All detectors will be accompanied by an individual control of pinholes size and 3 additional replaceable filters for adjusting the energy range in each system.

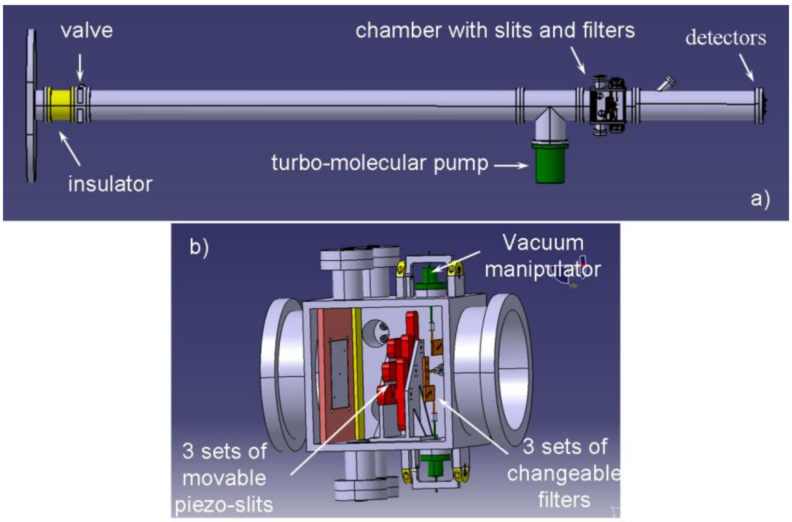

Fig. 1 Conceptual design of PHA diagnostics system for W7-X: a) main diagnostics port; b) details of the chamber contains three sets of movable slits with piezo drives and pinholes, and three interchangeable filter systems

The proposed PHA diagnostic is intended to provide the spectral energy distribution with energy resolution not worse than 180 eV along a central line of sight. The system will consist of 3 single Silicon Drift Detectors (SDDs). The measurements will be taken along sightlines through the center of the plasma. In the diagnostic all detectors, operated with different filters will be installed on the horizontal port AEK50 on W7-X. Each detector will record an X-ray spectrum in three different energy ranges (energy channels) from 400 eV to 20 keV. This will allow to enhance the sensitivity for particular

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The MFS system will be realized on port AEN20 as a part of the so-called flexible SX camera system on the AEM10-AEN10-AEO10 port combination. This diagnostic will consist of a set of semiconductor detectors using different filters, current amplifiers and a memorizing system. The temporal resolution should be high enough to allow monitoring of fast events.

A number of computer simulations using RayX code for MSF diagnostic have been performed using different geometry and plasma conditions. An analysis of a dark current and noise of the considered detectors showed that acceptable level of the detected current should be higher than 100 nA. Basing on the calculations it was established that the distance from plasma center to pinhole should be 2.5 m and the distance from pinhole to the detector - 0.20 m. Taking into account influence of magnetic field on diagnostic components, the turbo molecular pump has been placed at 6 m from the plasma center.

Tests carried out on different types of detectors showed that FLM type detectors with 380 m of active layer, surface 5×5 mm and 10 pF of capacity, produced by Institute of Electron Technology in Warsaw are the best candidates for MFS diagnostic. Therefore, three detector arrays composed of 5 thick FLM-type detectors have been purchased. The detectors has been mounted on Alumina with a capacitor and resistor integrated to the board (SMD-technology).

A number of computer simulations have been made to obtain a conceptual design of PHA and MFS diagnostics foreseen for the Wendelstein 7-X stellarator. In the case of PHA diagnostics a conceptual designs have been developed, based on the use of the detectors in one main port (with all components inside). It was established that this diagnostics will be based on 3 detectors covering different ranges of spectrum, all viewing the central plasma. In the case of MFS system the conceptual design has been made and proposed detector arrays have been purchased.

C-, O- monitor system for W7-X

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The "C-O- Monitor" is a particular construction of a soft X-ray spectrometer with high throughput and time resolution which will be placed on AEK 30 port of the stellarator W7-X. The purpose of this spectrometer is constantly monitoring the impurity level by measuring Lyman-α line intensities emitted by hydrogen-like ions of boron, carbon, nitrogen and oxygen.

Data acquisition system is an important part of every diagnostic of W7-X experiment. It should not only provide reliable measurements but also have to be easily synchronized with the global data acquisition system. Beside providing the data measured by detector it is also advisable to register the system setup parameters as e.g. high voltage value, discrimination levels, pressure etc.

Regardless that the spectrometer will be fixed at its wavelength and position during normal operation, some control system associated with closing and opening of the valves or setting the electrical parameters are necessary. Because of restricted access to the torus hall, all the systems have to be operated remotely.

A part of the data acquisition and control system is also the safety feedback loop protecting both, the main plasma vessel (e.g. from contamination of plasma by counter gas in case of serious leakage) and the spectrometer itself (e.g. from overheating its interior in case of too high level of stray radiation).

Defining the data acquisition and control system is necessary in order to define interface to data acquisition system of W7-X experiment (e.g. analog-to-digital converters), estimate the type and length of cables etc. It is also necessary to take into account the conditions in vicinity of the stellarator, i.e. the magnetic field and the possibility of neutron radiation.

Based on experience gained during soft X-ray spectroscopic studies at JET and ASDEX-U experiments, a modified multistrip proportional counter has been chosen as the radiation detector.

The construction will be based on the counter working at ASDEX-U experiment. The great advantage of this detector is its simplicity, low noise level and immunity against serious damage by neutrons and other high energetic radiation. Measures against neutrons will be taken in order to reduce background intensity induced by such radiation. The main critical point of this detector type (in case of soft X-ray detection) is the counter window which has to separate the atmospheric pressure counter gas against the spectrometer vacuum. This requires a compromise in foil thickness with respect to mechanical properties of the foil on one hand and reduction of the intensity associated with high absorption in this energy range on the other hand. Consequently, there always exists a certain risk for leaking or foil burst and thus the spectrometer system has to be equipped with an appropriate set of valves, pressure gauges and feedback systems, in order to protect the spectrometer itself and the main plasma vessel from contamination with counter gas and air.

The energetic resolution of the gas counter, especially in the soft X-ray region (low energy of quanta) is rather low and usually do not exceed 30%. Therefore it is impossible to determine the line intensity based only on pulse height spectrum (the technique commonly applied for hard X-ray or γ radiation). Nevertheless the energetic spectrum has to be determined in order to identify pulses with energy associated with the observed spectral line and cut of the noise. Moreover by setting relevant discrimination levels one can cut-of 'unwanted' pulses associated e.g. with higher order of diffraction or neutrons. There exists a risk that in case of very intensive irradiation of the detector (e.g. by strong flux of neutrons) because of low mobility of positive ions, the positive space charge could appear. This phenomenon can change the detector properties, e.g. its dynamic range. Therefore, apart of cutting-off high energetic pulses, some information about its level ought to be stored too.

Two options of data acquisition systems were considered.

In the first version only counts registered in each channel will be registered. Additionally pulse height spectrum in one, selected channel will be monitored in order to check and control levels of discrimination.

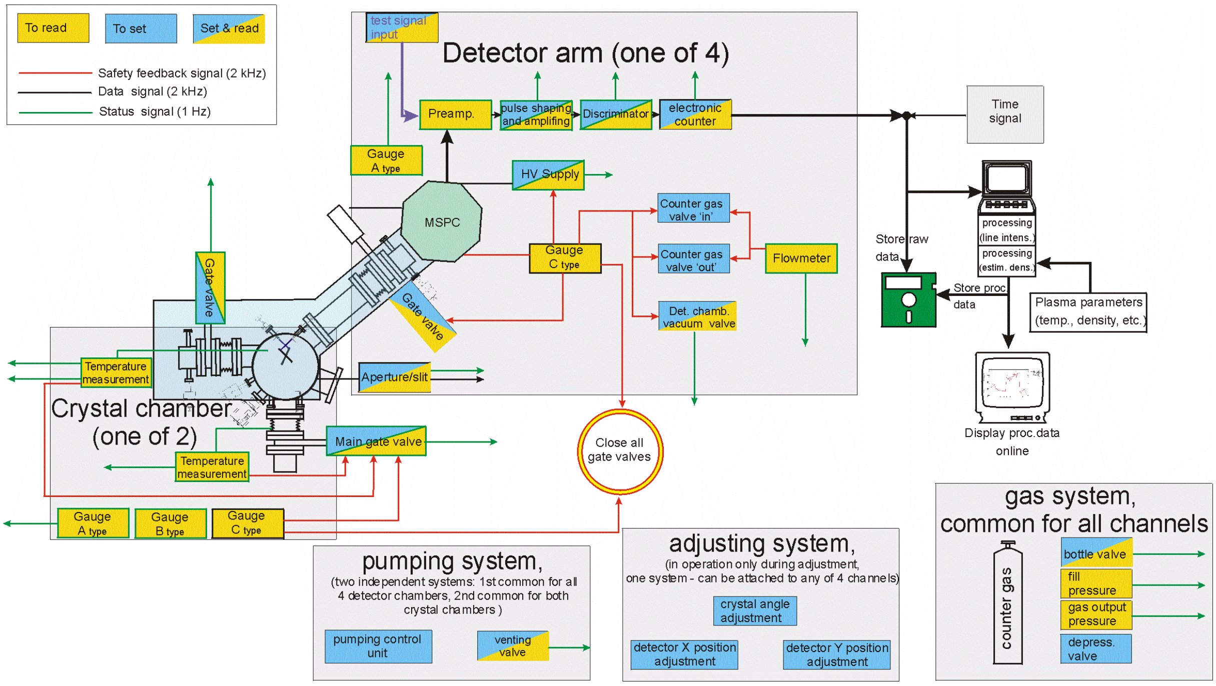
Apart of the measured data produced by detectors there exist a set of parameters which also should be stored. Most of them as settings electronic systems or counter gas flow, can to be stored with low temporal resolution (order of 1 Hz or even lower). Some of the parameters should also be stored with high time resolution, because they are important for the data analysis (as position of the input aperture) or because they are important for safety of the machine.

It was decided that all safety procedure will be not based on hard-wired electrical connections but will be realized via computer acquisition and control system. This solution allows to define complex safety procedures, associated with simultaneous closing of several valves and switching of several subsystems. The signals which will be used in the safety feedback system have to be read and transferred with – as fast as possible – time resolution.

Standard reaction in case of any problems will include closing of all electropneumatic gate valves.

As the access to the torus hall will be restricted during working week all systems of the spectrometer have to be remotely operated type.

During standard operation the spectrometer should be fixed at its position and selected wavelengths so some of the control system will be used only during the adjustment phase. The adjustment will be performed only before start of the normal operation of the device and then all angles and positions should be fixed. In case of the necessity to perform re-adjustment (e.g. after major repair-work) one need to provide also some control system allowing to perform this task. In order to reduce the costs and number of redundant systems it was assumed that there will be only one set of adjusting devices (motors and controls) which can be connected to each of the spectrometer channels.



Development and application of neutron diagnostics based on activation method for magnetic confinement devices (W7-X)

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MCF fusion experiments that involve deuterium or deuterium tritium plasmas can generate more than 10^{12} neutrons per second. At these emission levels, it is possible to obtain information about the plasma using various techniques that measure the neutron fluxes and energy distributions. The neutron emission rates and energy spectra of neutrons for plasmas with Maxwellian energy distributions can provide information about ion temperature and fuel density, and the generated fusion power can be determined. For discharges with significant additional heating, the ion distribution functions and ratios of thermal and non-thermal reaction rates can also be evaluated.

Neutron activation is one of the technique that is used in many MCF devices to determine the neutron fluence or energy spectrum at specific locations around the machine [1]. Neutron activation is well-suited for accurately and precisely monitoring the fusion power by measuring the neutron yield. This technique gives stable and linear responses to the fusion power level. This method is based on recovering information about neutrons by registering the products of induced reactions. Samples of selected materials are used as detectors. During the irradiation of the samples, reactions that create radioactive nuclei are induced. The chosen materials have relatively high reaction cross-sections with neutrons in the specified energy ranges. The reactions are selected so that their products decay with gamma-ray emission and can thus be detected using gamma spectrometry. Exceptionally, reactions leading to beta-radiation are also used. The sample materials can be chosen such that neutrons with energies of 14- and 2.5-MeV and scattered neutrons are measured separately.

The uncertainty in measurements performed with activation techniques depends mainly on the accuracy of the cross-section data and on the geometry factor. It is generally accepted that the total yield of the 2.5-MeV neutrons from large tokamaks can be determined with an accuracy of better than 10%.

The measured neutron fluence at the irradiation point is related to the total neutron production by applying a calibration factor that is determined using neutron transport calculations (e.g., MCNP code), taking into account the geometry of the detector and the geometry and composition of the samples. Benchmark experiments, using suitable calibration neutron sources, must be performed to check the reliability of the calculations.

The reactions needed to perform useful measurements on a fusion device must meet several requirements. The isotopes naturally occurring in the activation materials must have sufficiently high reaction cross-sections in the relevant neutron energy range. At the same time, the products of these reactions should decay with appropriate half-lives and emit suitable gamma photons.

The neutrons at JET during deuterium operation come from d-d fusion and in small percentages from tritium burn-up; the neutrons are originally of 2.5- and 14-MeV energies, respectively, which are broadened due to the plasma temperature and the applied heating systems. The typical plasma pulse at JET takes usually about 30 – 60 s. The main neutron emission, on the other hand, occurs only during the additional heating phase, mainly with neutral beam injection (NBI), which only lasts for a few seconds.

The chosen reactions should lead to decay products with proper half-lives. Because of properties of the applied gamma spectrometer, the reaction products must emit gamma lines with energies between about 100 keV and 2000 keV. It was assumed that the most useful cross-sections are at least of the order of hundreds of millibarns.

An additional, very important issue is the accuracy of the available cross-sections. We strive to use only verified and current nuclear data libraries like ENDF/B-VII.0 or IRDF-2002.

The reactions considered for measuring 2.5- and 14-MeV neutrons are presented in Tab. 1 and 2, respectively. Threshold-less reactions, like radiative capture, are used for slowed (scattered) neutron measurements. We also registered this reaction type during the described experiments.

Table 1 Selected reactions for 2.5-MeV neutrons

No	Reaction	Threshold [MeV]	Product half-live
1	Ti-47 (n,p) Sc-47	1.8	3.3 d
2	Fe-54 (n,p) Mn-54	1.8	312 d
3	Ni-58 (n,p) Co-58	1.6	71 d
4	Se-77 (n,n') Se-77m	0.2	17 s
5	Br-79 (n,n') Br-79m	0.2	5 s
6	Sr-87 (n,n') Sr-87m	0.4	2.8 h
7	Y-89 (n,n') Y-89m	1.2	15.7 s
8	Zr-90 (n,n') Zr-90m	2.3	0.8 s
9	Cd-111 (n,n') Cd-111m	0.5	49 m
10	In-115 (n,n') In-115m	0.6	4.5 h
11	Er-167 (n,n') Er-167m	0.3	2.2 s
12	Hf-177 (n,n') Hf-177m	1.3	51 m
13	Au-197 (n,n') Au-197m	0.5	7.7 s
14	Pb-207 (n,n') Pb-207m	1.6	0.8 s

Table 2 Selected reactions for 14-MeV neutrons

No	Reaction	Threshold [MeV]	Product half-live
1	Al-27 (n,p) Mg-27	4.3	9.5 m
2	Al-27 (n,α) Na-24	6.8	15 h
3	Ti-46 (n,p) Sc-46	3.8	84 d
4	Ti-48 (n,p) Sc-48	7.4	44 h
5	Fe-56 (n,p) Mn-56	7.0	2.6 h
6	Co-59 (n,α) Mn-56	8.5	2.6 h
7	Co-59 (n,2n) Co-58	10.8	71 d
8	Zn-64 (n,2n) Zn-63	12.6	38.5 m
9	Zr-90 (n,p) Y-90	7.6	3.2 h
10	Zr-90 (n,2n) Zr-89	12.2	4.2 m
11	Nb-93 (n,2n) Nb-92	9.1	10.1 d
12	Mo-92 (n,2n) Mo-91	12.8	15.5 m
13	Au-197 (n,2n) Au-196	8.8	9.6 h
14	Pb-204(n,n')Pb-204m	2.7	67 m

The calculations have been performed assuming that the overwhelming majority of the neutron emission from the JET pulse takes place only during the NBI heating period, which usually lasts not more than 10 seconds. Six different threshold reactions for 2.5-MeV neutrons were recorded: ^{47}Ti(n,p), ^{54}Fe(n,p), ^{113}In(n,n'), ^{58}Ni(n,p), ^{89}Y(n,n') and ^{115}In(n,n'). We shall discuss more carefully the data obtained from three of them: ^{58}Ni(n,p), ^{89}Y(n,n') and ^{115}In(n,n').

The obtained reaction rates are presented in Fig. 1 as a function of total neutron rate.

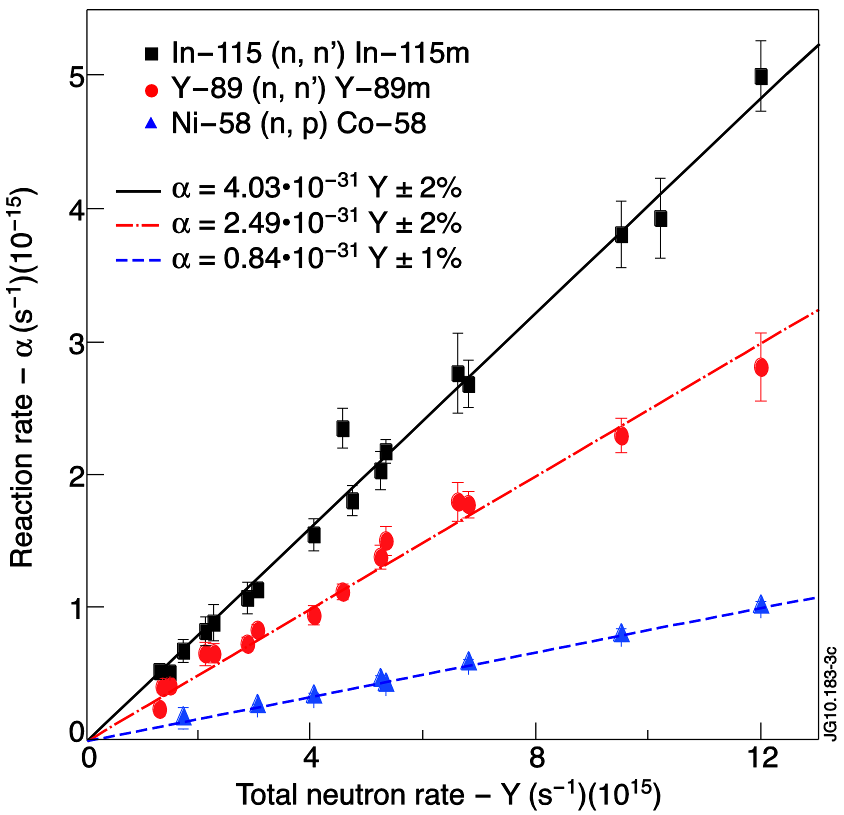

Fig. 1

One can see that the reaction rate varies roughly linearly with the neutron emission. Some scatter in these results can be explained by the uncertainties in determining the details of the measuring procedure (the cooling and counting times were measured by a wrist watch, not automatically) and also by the uncertainties in the detector calibration and counting statistics.

Detection of the delayed neutrons from activation of fissionable materials in the neutron field at fusion-plasma devices

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Measurement of delayed neutrons emitted from irradiated samples of fissionable materials is a base for calculation of the neutron flux in which the samples were activated. The constructed measuring device, DET-12, consists of two parts: measurement chamber and electronic equipment. A sample of fissionable material, irradiated in an unknown neutron flux, is placed inside the chamber in a fixed position. The emitted delayed neutrons are then slowed down in moderator layers of the chamber and then registered in ^{3}He detectors. Tests of a laboratory operation of the DET-12 device were performed and the detection efficiency was determined.

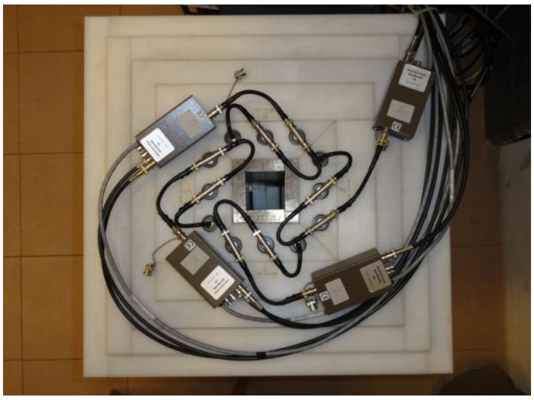

Fig. 1 Top view of the DET-12 device (cover removed)

The electronic lines were assembled and checked. The neutron detectors are connected in groups of three to one preamplifier, creating four independent units. All detectors were placed in their working positions inside the measuring chamber. The ^{252}Cf source was used as a neutron source which has the energy spectrum quite similar to that of delayed neutrons (Fig. 3). The neutron emission from the source during the test measurement was found as 1020 neutrons per second, according to the source certificate taking into account the half-life period of the source and the neutron activity coefficient. The source was placed inside the central channel of the chamber at the level fixed by the half of the active length of the detectors. First aim of the test measurements was to adjust working parameters of each group of detectors to obtain a very similar work of each one. Pulse height spectrum for each group was observed and working parameters (high voltage supply, amplifier gain and shaping time) were adjusted.

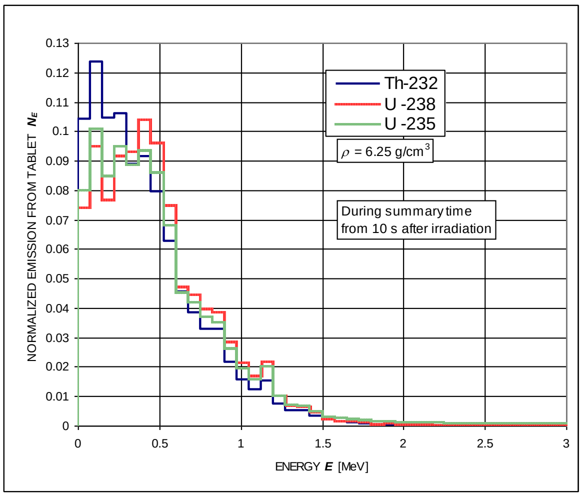

Fig. 2 Normalized emission vs energy (MeV)

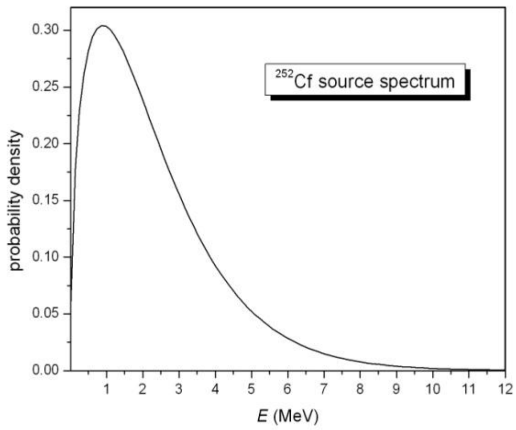

Fig. 3 Energy spectra of the delayed neutrons and of neutrons from the ^{252}Cf source

The next purpose was to evaluate neutron detection efficiency in test measurements and to compare it with MCNP calculations. Four measurements, twice with the californium source and two measures of background, were performed. The average count rate (background subtracted) is 191.41 s^{-1}, which defines the detection efficiency as 18.8 %.

The DET-12 device was modelled with the CAD program according to the technical design. Then the CAD model of the DET-12 was exported to the “sat” format in order to covert it with the MCNP Visual Editor. The created file is a geometrical part of an MCNP input file. The energy spectrum of the ^{252}Cf source used in the calibration measurements was modelled using a built-in Watt fission spectrum which is commonly used by the MCNP users. The probability density of neutron emission *p(E)* for ^{252}C is given

[3] as $p(E) = C\exp(-E/1.025)\sinh\sqrt{2.926\,E}$, where C is a constant and E is the energy expressed in MeV (Fig. 2). Composition and density of almost all materials used to build the DET-12 – like cadmium, bismuth, polyethylene and boron carbide – is well known except of the ^{3}He detectors. The manufacturer releases only pressure (3800 Tr, *i.e.* 5 atm). It was arbitrary assumed the commercial detectors to be filled with 95% of ^{3}He and 5% of ^{4}He. The density of helium filling the commercial detectors was evaluated using the ideal gas law. The Monte Carlo simulations were carried out on a PC computer and the average number of reactions in one cubic centimetre in the volume of all twelve detectors per one source neutron was calculated. The obtained value is $1.62755\cdot10^{-4}$ cm^{-3}. Finally, the reaction rate in all detectors together is 244.58 counts per second, which defines the efficiency of 24 %. The Monte Carlo simulations do not include neither dead time nor efficiency of the detectors. Moreover, the real composition of the gas in the detectors may be different from the assumed. Usually small amounts (below 1%) of CO_2 or both Ar and CO_2 are added as a quench gas, which were not included into the Monte Carlo model for the sake of lack of information released from the manufacturer. The difference between the simulation and experiment results will be taken into account in further modeling of operation of the set up, especially at absolute calibration of neutron fluxes.

Numerical analysis and evaluation of the structural mechanical behaviour of magnet system components of W7-X

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The objective of the task in 2010 was to implement the detailed model of NPC2-Z2 connection, developed already in previous year, in ANSYS 36degree Global Model of W7-X and to determine the connection static load bearing capacity. To this end the complete set of the Global Model (GM) files was received from IPP. The files have been modified at WUT (the geometry and finite element model were refined in the area of NPC2Z2 connection) and new material properties were introduced according to the IPP request from 8th Nov. 2010. The results obtained allowed to conclude what follows:

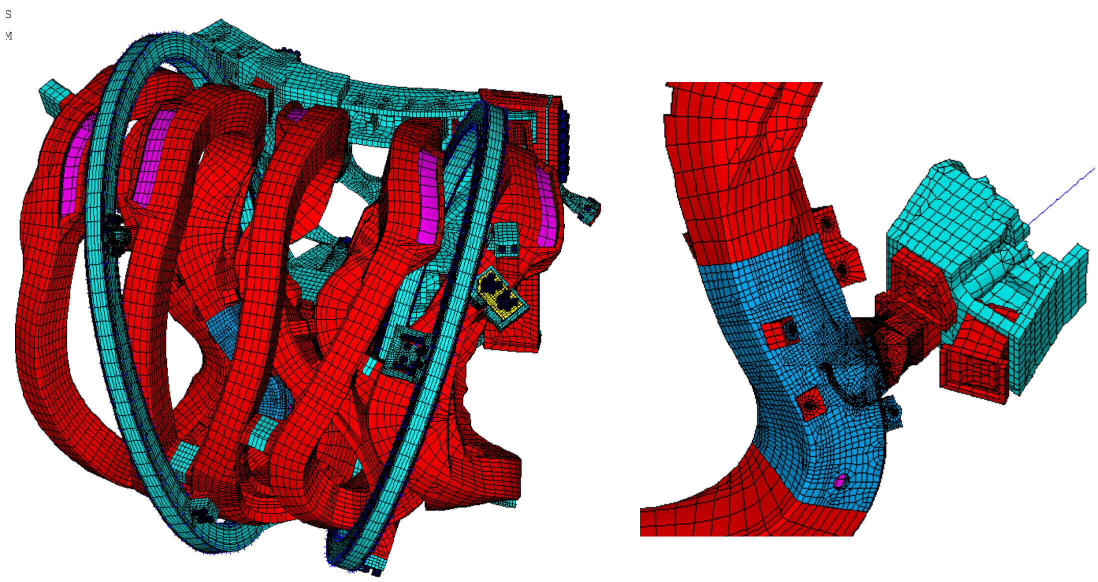

Fig. 1 The 36 degree Global Model with NPC2Z2 connection detailed sub-model

1. The nonlinear behaviour of the connection is different than observed when analysed as a separate model (calculations performed in 2009). The flexibility of the structure, defined as

relation displacement/load changes, in the range of loads up to load ratio $\lambda_{eml} \leq 2$ (see Ku/Ku1 in Table 2) is almost constant and close to 1, whereas in case of the connection analyses as separate models the flexibility characteristics was much more nonlinear.

2. The large plastic regions observed within the structure (especially the fully plastified bolt) are mainly the result of new assumed material models. Those material models lead to large plastic deformation within the structure. From the numerical point of view the implementation of such material model is inappropriate and leads to unrealistic results.
3. In general after incorporation of the submodel into the GM the connection becomes "safer" than when analysed individually, which is understandable taking into account the changes in stiffness of the analysed model.

4.2 Contribution to ITER

Nuclear Data studies/experiments in support of TBM activities (At no cost for EURATOM Contract of Association. F4E grant)

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Tritum production rate measurement metod in LiPb material

In the frame of the EFDA Work Program the field of Nuclear Data and Neutronics is embedded as a part of the neutronic aspects in the design, safety and future operation of the ITER, IFMIF and DEMO including the neutronics tasks for TBM. For the purpose of the further development and upgrade of the European Fusion File (EFF) and the European Activation File (EAF) dedicated neutronics benchmark experiments are realized. One of them is helium-cooled lithium-lead (HCLL) TBM mock-up serving for design and performance analysis of the DEMO Test Blanket Modules to be inserted in the ITER for testing purposes.

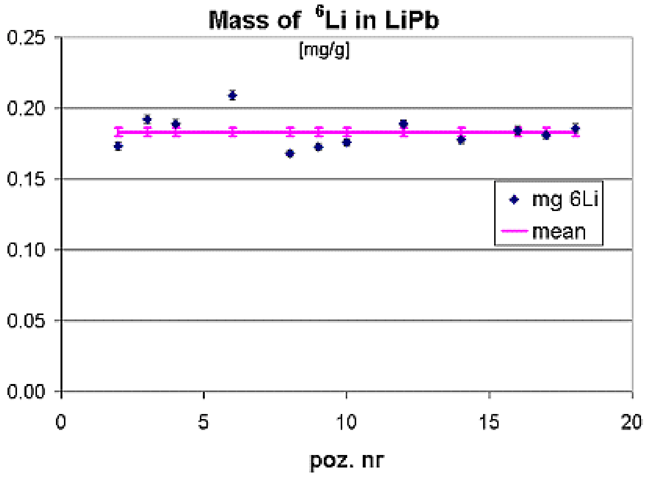

Fig. 1 Results of ^{6}Li measurements in LiPb in MARIA experiment

The objective of the presented work performed in the frame of F4E grant was to develop ^{3}H measurement procedure directly in LiPb material with the use Liquid Scintilator Technique (LSC). Elaborated method has been tested on samples made from LiPb material used for Frascati HCLL TBM mock-up construction. Nuclear reactor MARIA in Poland has been used as neutron source for this purpose. The Li_2CO_3 anf LiF samples have been used as materials in two reference ^3H analytical methods: respectively Dierckx and developed in EFDA-F4E grant(TW6-TTMN-002B) LSC method in LiF material. The content of ^6Li isotope LiPb material was assessed (Fig. 1). Our results proved that lithium used for LiPb production was depleted. Finally the elaborated method has been successfully applied to measure tritium activity in samples irradiated in Frascati HCLL TBM mock-up neutronics experiment. The experimental results compared with MCNP calculation results are presented in Fig. 2. It proved once again that ^6Li content is less than in material with natural isotopic composition.

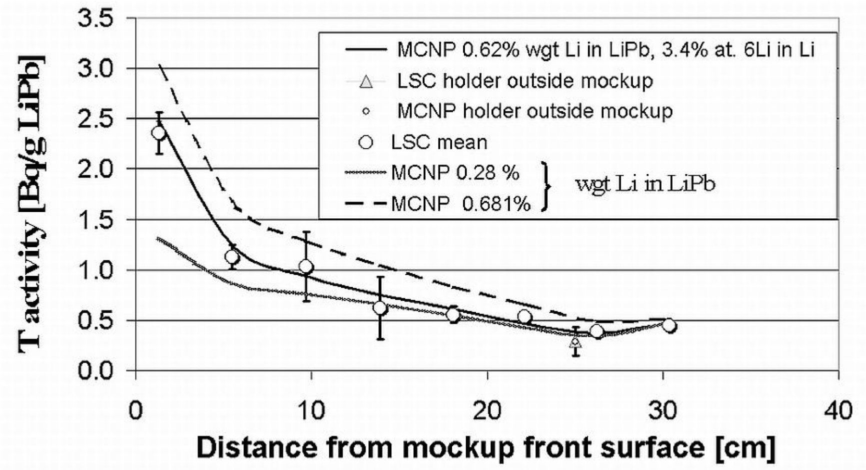

Fig. 2 Results of T measurements in LiPb in FRASCATI experiment