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newsletter

EUROPEAN FUSION DEVELOPEMENT AGREEMENT

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Contents

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News

ITER Director-General Nominee Ikeda visits Cadarache

On the 24th of November, ITER Director-General Nominee Kaname Ikeda visited for the first time the CEA Cadarache Centre as well as the future ITER construction site. His visit focussed on discussing preparations for the arrival of the ITER Project Team for which he will be responsible. He was welcomed by Bernard Bigot, French High Commissioner for Atomic Energy, and representatives of the European Commission.

From left to right: B. Bigot, K. Ikeda, M. Chatelier and P. Garin visit the future ITER construction site.

P.H. Rebut awarded Hannes Alfven prize

The Plasma Physics Division of the European Physical Society has awarded the 2006 Hannes Alfven Prize to Dr. Paul-Henri Rebut, for his lasting contributions to fusion research. The prize will be presented on the first day of the Annual Conference of the EPS Plasma Physics Division in Rome on the 19th of June, 2006.

Chinese Prime Minister visits ITER site

On the 6th of December, the Chinese Prime Minister Wen Jiabao visited the ITER construction site in Cadarache and Tore Supra. The Chinese leader stressed the interest that the whole world has in developing energy sources to replace dwindling fossil fuels, and he expressed the hope for an abundance of clean and cheap energy in the 21st century, to facilitate a sustainable development of the economy.

Official inauguration Cadarache ITER joint work site

D. Gambier cuts the ribbon held by K. Ikeda to open the ITER Joint Work Site in Cadarache in the presence of P. Amenc-Antoni, W. Burkart and regional politicians.

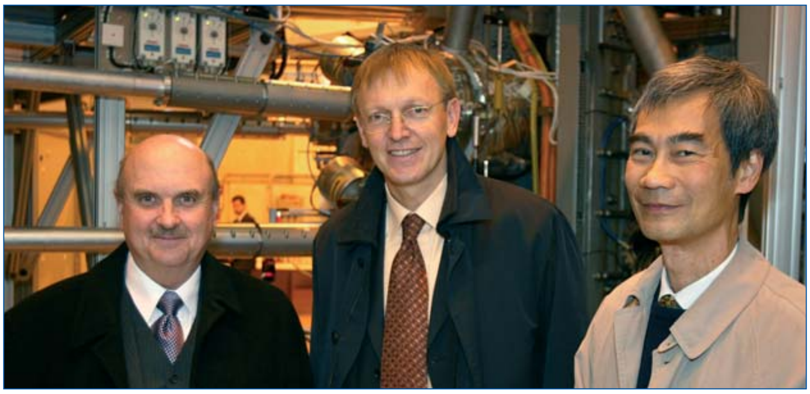
The ITER Joint Work Site in Cadarache was inaugurated on Thursday 15 December 2005 by a ribbon-cutting and olive-tree-planting ceremony, in the presence of regional politicians and representatives of the embassies and consulates of the ITER Parties. Pascale Amenc-Antoni, director of the CEA Cadarache centre, welcomed the participants to the ceremony and gave an overview of the facilities put in place to host the ITER team. Didier Gambier, representing the European Commission, welcomed the representatives of the ITER Parties and assured ITER of continuing European support.

Kaname Ikeda, Director-General Nominee, made an immediate impression on the regional politicians by expressing, in French, his joy at the opportunity to start working at Cadarache on such an important project. Dr. Werner Burkart, Deputy Director General of the IAEA, spoke of an historic event, in an historic year for the IAEA, and expressed his satisfaction at the progress in the ITER project. Finally, Dr. Michel Chatelier, head of the fusion department in Cadarache, said that he looked forward to hosting the ITER team and a fruitful cooperation. The Joint Work Site offices will start to be occupied from January 2006 onwards.

News

Commissioner Janez Potočnik visits Switzerland

On November 16, 2005, the Swiss Federal Institute of Technology (EPFL) received the European Commissioner Janez Potočnik.



From left to right: Prof. Giorgio Margaritondo, Janez Potočnik, and Prof. Minh Quang Tran.

He was welcomed for a tour of the Plasma Physics Research Center (CRPP) on the site of EPFL. Prof. Giorgio Margaritondo, Vice-President of the Swiss Federal Institute of Technology and Prof. Minh Quang Tran, EFDA leader and director of CRPP, accompanied and guided the Commissioner on the tour, which included a presentation of the fusion activities of the Euratom-Confédération Suisse Association, a visit to the TCV tokamak, and a visit to the European test stand Facility of the 170 GHz gyrotron, which is currently being built in view of ECRH use on ITER. Janez Potočnik noted that CRPP is a leading European competence center for gyrotron and ECRH plasma heating systems.

India becomes full partner in ITER project

At the 12th ITER Negotiation Meeting, which was held on the 6th of December in Korea, India was welcomed as a full partner to the ITER project.

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At the beginning of the meeting, the current ITER partners (EU, Japan, China, the Russian Federation, the Republic of Korea and the USA) unanimously and enthusiastically welcomed the new partner, after which a Delegation from India, for the first time, joined the meeting and participated fully in the discussions that followed.

The Head of the Indian Delegation, Dr. V.P. Raja, remarked that with India joining ITER, now more than half of humanity has entered into a partnership to work towards the solution of one of the most pressing problems for mankind, the energy problem. He further explained about India's enormous energy needs, caused by an accelerating economy and growing expectations of India's citizens for a better quality of life, and reminded the other partners that India has already designed and built two tokamak devices, ADITYA and the steady state superconducting tokamak SST 1.

New Joint European Master in Fusion Science

Seven institutions for higher education have launched a Joint European Master in Nuclear Fusion Science and Engineering Physics (FUSION-EP). The aim of the Masters programme is to provide high-level multinational research-oriented education in fusion-related engineering physics, in close relation to the research activities of the partners.

The partners in the Consortium are the Universiteit Gent (Belgium), Université Henri Poincaré (Nancy, France), Kungliga Tekniska Högskola Stockholm (Sweden), Universidad Complutense de Madrid (Spain), Universidad Carlos III de Madrid (Spain), Universidad Polytécnica de Madrid (Spain), and Universität Stuttgart (Germany). The partners have a long relationship in the framework of the European Fusion Programme.

The combined and harmonized teaching and research of the seven institutions offers a far greater variety of competences in the field of fusion science and engineering physics than could be provided by each of the single institutions, and therefore guarantees a significant added value for the students in terms of specialisation opportunities.

The Masters programme is coordinated by prof. Guido van Oost (University of Gent). All information concerning application procedures, progamme and selection criteria can be found at the website www.em-master-fusion.org.

Events

Science on Stage

From the 21st until the 25th of November, 400 teachers gathered at CERN in Geneva for the first Science on Stage festival, an opportunity for European teachers to exchange successful and innovative teaching methods and materials. EFDA participated to the festival with two workshops on fusion, organised by Chris Warrick (UKAEA) and Mark Tiele Westra (FOM).

The goal of Science on Stage (which is the successor of Physics on Stage) is to strengthen the awareness and interest of young people in science and technology by increasing the attractiveness of science lessons through the promotion of exciting ideas. National Steering Committees select the best ideas and people from their respective countries, and the national winners present themselves on a large exhibition at the festival.

The EIROforum Teaching Science Award was awarded to a French school, for a project where 12-year old children build a box full of electronics and simple cameras, which was subsequently taken up by a weather balloon to take stunning photographs of the earth’s atmosphere from a height of 35 (!) kilometers.

The festival was organised by EIROforum, a collaboration between seven European intergovernmental research organisations (CERN, EMBL, ESA, ESO, ESRF, ILL and EFDA), that are responsible for large infrastructures and laboratories.

Fusion at the Communicating European Research conference

On 14-15 November, the second Communicating European Research conference took place in the Brussels Expo. In the exhibition, the European Fusion Community presented itself with three stands presenting EFDA, the Fusion Road Show, and the ITER project, which were organised by European Commission’s DG-RTD, the UKAEA, and FOM. The ITER stand, which received visits by the media and by Commissioner Potocnik, received the award for the best stand at the fair from the Director-General for Research, Achilleas Mitsos.

The conference, which drew around 2100 participants, focussed on the science communication aspects of research projects supported under the EU's Framework Programme. The goal was to improve communication, outreach and dissemination of research results to the public and the press at a European level.

In his conference-closing speech, Mr. Mitsos pointed to ITER as the leading example of how European research could and should seek success by expanding to the global level.

The ITER- mini-expo, a small version of the travelling exhibition Fusion Expo, won the prize for best stand at the exhibition.

ITER presented to European Industry

Over six hundred representatives from European industry and fusion research institutes gathered in Barcelona on 13/14 December, for a two-day workshop named “ITER – Opportunities for European Industry”. The goal of the workshop was to inform European companies about the ITER project, and to discuss opportunities for their involvement in its construction. The workshop followed an initiative of the Committee for Fusion Industry of the European Commission, and was hosted by the Spanish fusion Association CIEMAT.

Visitors of the industry exhibition at the Barcelona workshop.

During the ITER-project, the European industrial companies that will construct the European part of the ITER-device will use high-tech knowhow developed in fusion research institutions around Europe. It is expected that a lot of technological innovation will result from the exploitation of this knowledge, which opens many opportunities for high-tech companies to participate fruitfully to the project. Fusion research institutions themselves will benefit from industrial knowledge methodologies.

The workshop, which included a fusion industry exhibition, offered a practical possibility for industrial parties to meet fusion experts from ITER and EFDA. An Industry Suppliers Database, to which interested companies are encouraged to register, was presented at this occasion. The database will be made available on the EFDA website in the near future.

Correction

Due to a printing error, the photo caption on the cover of the October newsletter was missing. It should have read: “Cheers! A toast to the new EFDA CSU office in Barcelona. From left to right: J.Sánchez (CIEMAT), Mrs. L.Rodríguez, E. Di Pietro, Mrs. Vila, Mrs. Belmonte, M. Mills, M. Nickl, and Mr. Galván, from the office construction company.

JET

Enhancements for JET beyond 2006: the diagnostic projects

Authors: Jérôme Paméla, Michael Watkins, Alain Lioure, Shakeib Arshad and Andrea Murari

In 2005 EFDA-JET embarked on a major new enhancements programme, aimed at supporting critical needs of ITER. The main elements of this programme are a new ITER-like first wall, a power upgrade, a new pellet injector and a set of new or upgraded diagnostics. The first three of these were described in previous issues of the EFDA Newsletter. Here we discuss diagnostics enhancements.

Diagnostics for ITER scenario development on JET

Plasma scenarios foreseen for ITER include the 'ELMy H-mode', the 'Improved H-mode' (often called the ' Hybrid mode') and 'Advanced Scenarios'. The first two are characterised by the formation of a transport barrier at the plasma edge which results in improved confinement, although this is accompanied by edge instabilities known as Edge Localised Modes (ELMs, see box).

Edge Localised Modes

The edge transport barrier in H-modes causes the build up of steep pressure gradients in the edge. This leads to periodic relaxations, called Edge Localised Modes (ELMs), during which energy and particles are transiently lost from the plasma. The magnitude and frequency of these events depends sensitively on operating conditions, and can range from mild to severe, whereby individual events may cause surface damage to the first wall. Demonstration of sustained high performance with mild ELMs is a high priority in further plasma scenario development for ITER.

In Advanced Scenarios, transport barriers occur deeper in the plasma. A major attraction of these scenarios is the possibility of steady state operation, with the plasma current being generated largely by the transport barriers (through the bootstrap effect) rather than by conventional pulsed transformer action. ITER scenario development on JET consists of exploring and optimising these scenarios in the most ITER-relevant conditions achievable, with the goal of sustaining high performance with acceptable power loading of the wall.

Diagnostic enhancements to support this effort concentrate on improved profile measurements as well as real-time control of profiles. The spectral coverage of the ECE system, which provides the highest quality temperature profile data on internal transport barriers and the edge pedestal, will be extended to access higher density regimes which are of increasing interest. An upgrade of the lithium beam system will allow edge current density measurements with high spatial and temporal resolution, and is expected to give access to key ELM physics. ELM diagnosis will be further enhanced with an upgrade of the edge LIDAR system, which will be able to resolve the steep edge gradients in the pedestal region. In addition, the real-time control infrastructure will be extended to execute additional and more sophisticated real-time analyses, and to include additional diagnostics desired by Task Forces.

Diagnostics related to the other major new JET projects

The ITER first wall, comprising beryllium in the main chamber, carbon fibre composites (CFC) at the divertor strike points and tungsten elsewhere in the divertor, is designed to minimise the tritium inventory (by minimising carbon surfaces) while maintaining adequate power handling capability and plasma performance.

The first ever test of an ITER-like wall in a tokamak is planned on JET, with installation of the wall in a shutdown in 2008/09. The test will focus on erosion/deposition processes and mass flow in the bulk and edge plasmas, ultimately aiming at demonstrating compatibility between high performance plasmas and the ITER-like wall. A set of new or upgraded diagnostics will be dedicated to this test. This will include additional quartz microbalances for erosion/deposition studies, a new high resolution camera for infrared thermography to study transient heat loading in the divertor and an upgrade of spectroscopic diagnostics for routine coverage of helium, beryllium and tungsten lines.

A new high frequency pellet injector will also be installed on JET, to study ELM control by pacemaking. A new fast camera is foreseen in support of this study, to observe pellet ablation and edge turbulence.

Prototype diagnostics for ITER

To support the sustained DT phase planned for ITER, a set of reliable burning plasma diagnostics will be required. Owing to its ITER-like plasmas, its ability to create high energy ICRF-accelerated alpha particles in DD discharges and its unique DT capability, JET offers an unrivalled environment for the development and testing of such diagnostics. Priorities to be addressed on JET include radiation-hard compact detectors for reliable neutron measurements in the space-constrained ITER environment; improved electronics for gamma and neutron detection, aiming at achieving a time resolution, signal-to-noise ratio and a neutron/gamma discrimination

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level suitable for ITER, with the possibility of real-time measurement for burn control applications; a neutron filter (e.g. LiH), aiming at eliminating the neutron background from gamma measurements to yield information on fast alpha particles; an ultra-thin detector for neutral particle analysis, to extend the diagnosed energy range to below 1 MeV, and to improve the discrimination of different ion species; a fast wave reflectometer to measure the isotope ratio in the core; and radiation-hard Hall probes aiming at complementing ITER magnetic diagnostics with steady state ex-vessel measurements.

These diagnostics will be installed progressively, with some becoming available in 2007, and the rest becoming available at the end of the shutdown for the installation of the ITER-like wall, in 2008/09.

JET technicians installing new equipment.

Preparing the heating of ITER by waves in the Ion Cyclotron Resonance frequency range.

Author: André Messiaen (ERM/KMS)

For the RF heating of large tokamaks like JET or ITER, high power-density antenna arrays are required to provide the large amount of power needed to achieve the required central plasma temperature of 10 keV. In ITER an amount of 20 MW of RF power in the Ion Cyclotron Resonance (ICR) frequency band of 40-55 MHz has to be radiated through a port surface measuring about 1.5m by 1.9m. Furthermore, large Edge Localized Modes (ELMs) will produce abrupt changes of antenna loading, capable of causing a safety shut-down of the high-power generators. The ITER ICRH launcher must thus be capable of high power density, and the matching system of the antenna array must tolerate large load fluctuations (in the order of 3 to 5).

At the ERM/KMS, the main lines of the EFDA R&D program in support of ITER are the construction of the so-called ITER-like ICRH antenna for JET, and the parallel conceptual designs studies of possible ITER launchers in which the antenna matching is either made internally (i.e. before the vacuum window), or externally. Whereas the former is developed by CEA, the latter effort is led by LPP-ERM/KMS. In this article we describe the solution with external matching, and the test stand that was build to test the scheme.

Figure 1 shows the antenna lay-out. An array of 24 radiating straps should be capable of providing the large power density with an affordable antenna voltage. The main advantages of this design are the absence of in-vessel remotely operated components to achieve the matching, and the use of 4-ports passive junctions that provide more uniform RF current distribution among the straps and minimize the number of matching circuits. Indeed, these junctions combine the 24 straps in 8 triplets which are linked to "conjugate T" or hybrid matching circuits which should provide the load resilience needed in presence of ELMy discharges. The straps will unavoidably be coupled to each other as they are radiating in the same medium. The intricate theoretical expectations

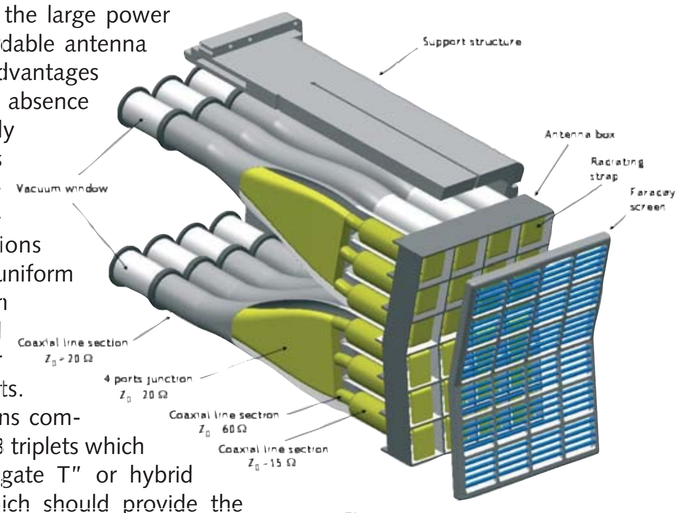

*Fig 1.
Design of an ICRH antenna plug for ITER.*

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of this coupling on the load resilience have to be checked before the installation of such a complex antenna array in ITER.

Fig. 2.
Photo of the inner part of one antenna triplet, fed by a 4-ports junction. The scale is 1/5.

The impedance matrix of the array remains identical when decreasing the scale length and increasing the working frequency by the same factor. It was therefore decided to construct, using a reduction scale factor of 5, a mock-up of the complete antenna array of 24 straps, grouped in 8 triplets by eight 4-ports junctions. This was achieved by the company TECHNIFUTUR (Sart-Tilman, Seraing, Belgium), through numerical machining starting from the original Catia 3-D drawings of the project. The frequency range corresponding to the full-scale system is 200-275MHz in the reduced-scale model. Figure 2 shows the inner part of one 4-port junction.

Whereas tests in absence of plasma are already useful, they are not capable to simulate all the electromagnetic properties in presence of plasma or to properly test the tuning algorithm. However, tests with realistic plasma-like load conditions can be obtained when a medium having a large dielectric constant faces the strap array. This is essentially the case because in such a medium it is possible to achieve wave numbers that are typical for the fast Alfvén wave that is launched from the antenna in a magnetized plasma. Water can be advantageously used as such a load. To avoid the spurious effect of wave reflection on the walls of the water tank, salt can be added to the water to provide sufficient wave damping.

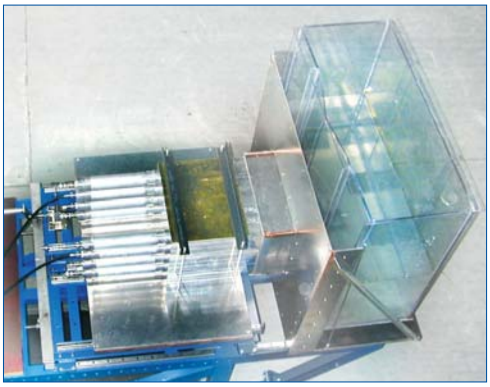


Fig. 3.
Mock-up of the antenna array, mounted in front of a water tank on a sliding table for controlling the distance between the array and the water load. The 8 outputs of the 4-ports junctions, where the measurement of the S matrix is done, are seen on the left side of the picture.

Figure 3 shows a picture of the complete ITER test stand with the mock-up and its water tank load. The array is mounted on a sliding support in order to adjust the distance between the array and the water tank, thus allowing to study the antenna loading as a function of this critical parameter. An extensive program has started in which various matching schemes are realized by means of external transmission line components and power sources, and their performances are checked and compared for various load conditions.

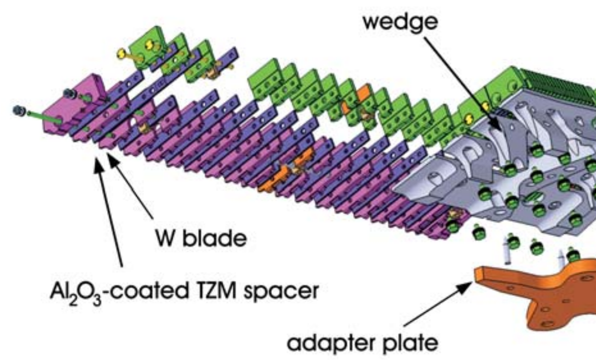
For more information contact the author at andre.messiaen@rma.ac.be

Bulk Tungsten R&D for the ITER-like Wall Project at JET

Author: Volker Philipps and Ralph Schorn

Research Centre Jülich (Association EURATOM-FZJ) – for a long time focussing on plasma-wall interaction and on testing plasma-facing structures – is contributing expertise to the ITER-like wall project at JET. R&D activities will address bulk tungsten components to be implemented into the divertor as load-bearing septum replacement plates.

Two options are being considered: the brazing of tungsten blocks on a Carbon Fiber Composit (CFC) substrate and stacks of tungsten lamellae. Both solutions are very challenging with respect to heat loads, joining techniques and electromagnetic loads. For the development of a brazed option, tests with different materials are carried out and evaluated at different temperatures. The brazing joint has to withstand operating temperatures of up to 1000 °C. Microstructural characterisation of the different CFC grades and of the brazing layers is currently being performed at Jülich.



The lamellae concept consists of stacks of tungsten and insulating spacers, held together by tie rods and being mounted onto a support structure. Differences in thermal expansion of the materials involved and mechanical pre-tension – being required to avoid detachment in case of electromagnetic loads due to disruptions

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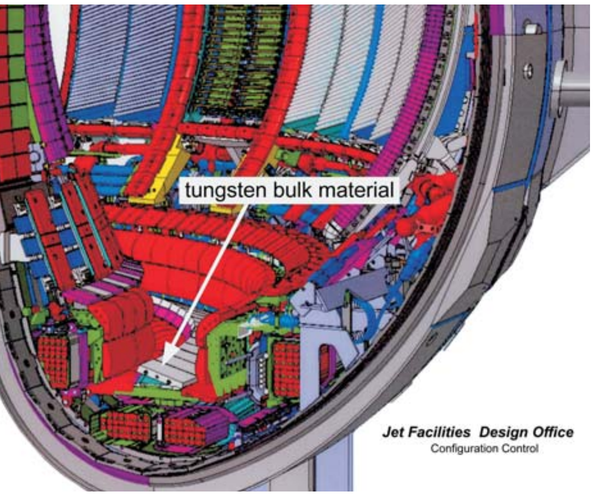
– define tight limits for the design.

Electromagnetic loads are critical for both options. The new design thus has to minimise eddy current loads by segmentation of loops and halo current loads by defining an optimal electric path. One of the first important results was the need for a considerable modification of the present support structure – both in order to reduce the electromagnetic loads and to cope with the loads transferred from the tungsten tiles.

Comprehensive thermal and electromagnetic analysis – applying analytic as well as finite elements methods – is performed in parallel with the design process. In addition, heat load tests are prepared in Jülich at FZJ's electron beam facility JUDITH and at the neutral beam test bed MARION. Extensive exposure to actual plasmas with relevant loads will take place in the TEXTOR tokamak.



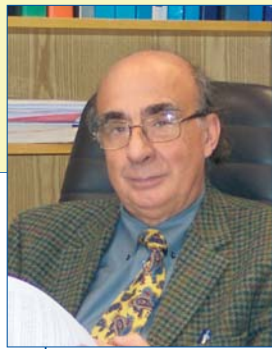
JET divertor with the location of bulk tungsten indicated.

Bottom view of a preliminary tungsten assembly (unfolded), showing the lamellae-structure.

Interview

Maurizio Gasparotto
New EFDA-Associate Leader for Technology

Dr. Maurizio Gasparotto (63) was born in Rome in 1942, studied at the G. Galilei Technical Institute in the same city, and received his Ph.D. in 1978 from the University of Rome. Since then, fusion has been a leading theme in his career. Dr Gasparotto is married, has three children, and is living in Munich.



On the 1st of November last year, you took up your new duties as the EFDA Associate Leader for Technology. Could you tell us something about your background and about your present role?

"I am a physicist, and have spent all my working life in R&D activities related to the application of plasma to produce energy: first magneto-hydrodynamic direct energy conversion, and subsequently fusion. I have been involved in the design, construction, and operation of the Frascati Tokamak and its Upgrade, in the assessment of JET for the operation at a higher magnetic field, and recently in supporting the design activities for the Wendelstein 7-X stellerator in Greifswald. In addition, I have been responsible for the technology R&D programme in ENEA, and for the field *Tritium Breeding and Materials* here in EFDA from 2000 up to 2003.

"My present role as EFDA-Associate Leader for Technology is to contribute to the coordination of the technological activities in EFDA while we are moving to a new, project oriented phase: the construction of ITER, the engineering validation and design activities for IFMIF, and the Long Term DEMO oriented technology activities (mainly materials and nuclear components development). These three together comprise the main technological lines of research towards the realization of a fusion power plant.

When in your career did you become interested in fusion?

"When I started to work at ENEA (the main research center in Italy for nuclear research, at the time called CNEN) in 1961, I was attracted to fusion research activities for two reasons: the curiosity and the wish to work in challenging areas from a scientific and technical point of view, and the idea of contributing to the realisation of something truly useful for everybody on earth. During all my working live, I have contributed to this field with great pleasure. I should also say that I have been very fortunate, as I have been involved in very challenging pro-

Interview

grammes, and I have worked with competent and very friendly people.

ITER will be built in Europe. Do you feel that the European Fusion Community has prepared itself adequately and is up to the task?

"I believe that from the technical point of view, Europe is very well prepared to build ITER. The tradition of the European Fusion programme in Europe, the success of many experiments (JET *in primus*), the design and R&D development starting with NET many years ago, and the involvement of industry in many key technology areas are all elements that will contribute to the success of ITER.

"There is one aspect in which, in my opinion, Europe has not prepared itself adequately: this is related to the number of fusion technology experts needed. The fact that the main experimental machines (with the exception of W7-X, which is in the fabrication phase) have been built many years ago, implies that the young scientists and engineers that now have to contribute to ITER have had only little construction experience. In addition, their number is not sufficient to face all the staffing needs in Europe for ITER, the Broader Approach, and the Long Term Programme. As a consequence of this shortage, we now have to create the new structures, such as the European and the ITER organisations, in a carefully optimised way, and start as soon as possible to attract and educate young and brilliant scientists and engineers.

Do you think the Fast Track development schedule can be maintained?

"Yes. I believe the Fast Track is a realistic time schedule for the scientific, technical and economic demonstration of the feasibility of a fusion power plant. To maintain it, three conditions must be fulfilled. First of all, obviously, the absence of some important unexpected show-stopper in the exploitation of the ITER and IFMIF programme on the physics or technology side. The second condition is that sufficient economic resources are allocated starting from FP7, in order to maintain and launch all the necessary activities. In particular, R&D on DEMO materials and some DEMO critical components (mainly the first wall, the divertor, and breeding blanket) should be increased. The third condition is that the international collaboration in the DEMO design and R&D areas are increased, in order to explore different concepts of potential interest in the Fast Track strategy.

"I believe that the present know-how in the field is such, that the probability of success is high and therefore the implementation of the Fast Track programme is extremely important considering the need for energy in the world.

What do you see as the main challenges of the ITER project?

"It is clear that in ITER, most of the components and related technology are very advanced and in some cases at the limit of our knowledge. This is evident from the large R&D programme that has been carried out up to now. From the technological point of view, I think we will be ready to launch the procurement of the long term items after a detailed design review, which the new ITER team has to carry out, with the help of all the experts. For a number of components which are not in the critical line for the ITER construction – such as those facing the plasma, and those related to the heating and current drive – additional research and development is needed.

"Considering that ITER will be built by seven Parties, each of them contributing in building *in kind* some components or part of them, it is also evident that the managerial effort to coordinate such a complex situation is absolutely not trivial. Considering these two aspects, the technical and managerial, perhaps we are facing one of the most challenging and complex projects in the world. A great project to be part of!

Feedback

EFDA would like to know if this newsletter is useful to you. Please send any comments or ideas you might have to:
mark.westra@efda.org

For more information see our EFDA website:

http://www.efda.org

and additionally

http://www.jet.efda.org
http://www.iter.org

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