INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR

ITER EDA NEWSLETTER

VOL.9, No. 5 MAY 2000

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, AUSTRIA

ISSN 1024-5642

SUMMARY OF THE ITER PHYSICS COMMITTEE MEETING

by Dr. M. Shimada, Head of ITER Physics Unit

Recent developments in the framework for ITER Physics activities were described in the September 1999 issue of the ITER Newsletter (Vol 8, No 9). This article provides a summary of the most recent meeting of the body responsible for overseeing the activities, the ITER Physics Committee, which was held on 24-25 January 2000 at the ITER Naka Joint Work Site, Japan. As usual the meeting was attended by the ITER Director, the Parties' Physics Designated Persons, the Chairs and Co-Chairs of ITER Physics Expert Groups and the JCT members involved.

Director's Introductory Remarks

Dr. Aymar reported the status of ITER. After a laborious one-year-and-a-half period, and collaboration with the Home Teams, the development of a "Reduced Technical Objectives/Reduced Cost" ITER has converged to a single design, which is referred to as "ITER-FEAT". While the design is conservative to meet its goal of $Q \geq 10$ in inductive plasmas, the machine is also capable of investigating steady-state plasmas with high bootstrap current. The investigation of steady-state regimes is facilitated by advanced features of ITER-FEAT, such as strong shaping, variety in heating/current drive, saddle coils external to toroidal field coils for suppressing resistive wall modes, profile diagnostics, etc. The hybrid mode of operation (only partly inductive current drive) provides a scenario for a long pulse, which will be useful for engineering tests.

An Outline Design Report had been completed and reviewed by the ITER Technical Advisory Committee before its submission to the ITER Meeting in Tokyo on 19-20 January. It is assumed that each Party will make a domestic assessment of ODR through July 2000 with interaction with JCT. The draft Final Design Report will be prepared by the end of 2000. Explorations will start in the spring of 2000 with the expectations that negotiations towards a construction agreement should start next year.

Arrangements were now in place to hold topical international fusion science meetings to ensure continuing interaction with the US Physics Community on generic issues of tokamak physics, including continued development and compilation of international tokamak physics databases which incorporate latest results from worldwide tokamak experiments

Reports from Expert Group Chairs

Diagnostics (A.J. Donné)

The role of plasma measurements for ITER-FEAT will be identical to that for ITER-FDR, and so the detailed measurement requirements are very similar. A limited number of changes arises, principally from the enhanced status in the experimental programme of advanced operational scenarios.

Access to the divertor in ITER-FEAT is reduced with respect to ITER-FDR, and it is expected that measurements in this region will be more difficult. For the long pulses (> 1000s), problems may arise with the measurement of plasma shape and position by magnetics particularly due to a small emf which tests have shown may be induced by radiation. An urgent task is measurement of change in reflectivity of plasma-facing mirrors.

MHD, Disruptions, and Control (O. Gruber)

Disruption-generated runaway electrons are eliminated completely by wall contact at safety factors of the disrupting core plasma below 3, at latest at q=1. A remaining issue is the slow current quench, where vertical displacement potentially results in high halo current and eddy currents.

Recent experiments suggest that direct current Electron Cyclotron Current Drive can be sufficient to stabilise Neo-classical Tearing Mode Islands. A complete suppression of Resistive Wall Modes and the performance above the no-wall kink limit are yet to be demonstrated.

Edge and Pedestal Physics (Y. Kamada)
The onset of confinement degradation at high density regimes with tolerable ELMs are urgent research areas. Dr. Kamada emphasised the need of a database encompassing pedestal, core and scrape-off-layer (SOL) because the physics in these three areas are interrelated. The "Grassy" ELM regime (or type II) provides an operation scenario with small ELM heat load, good confinement and no impurity accumulation. However, this regime is found only at high triangularity (>0.4) and high safety factor with low density range ($\sim 2 \times 10^{19} m^{-3}$ at Ip = 1 MA). A model of pedestal width has been developed, which includes turbulence suppression by magnetic and ExB shear. The model calculation of the pedestal pressure is in agreement with experimental data from C-mod and JET. The core confinement behaviour can be understood by stiff and non-stiff characteristics.

Scrape-off-layer and Divertor Physics (N. Asakura)
Establishment of an operational scenario with high density good confinement discharge with tolerable ELMs is an urgent issue. A new SOL and divertor plasma profile database at high triangularity and high density is important to facilitate model validation. Development of erosion/redeposition models and validation against experiments is an important issue, because this problem is related with tritium retention. Inclusion of Internal Transport Barrier (ITB) discharges in the SOL/divertor profile database is proposed. The edge density which is lower with optimised ITB plasmas than with inductive discharges with high density divertor is a problem. Difficulties with helium pumping is also an issue for ITB plasmas.

Energetic Particles, Heating, and Steady State Operation (C. Gormezano)
Large discrepancies remain between models of the effects of energetic particles in Toroidal Alfven Eigenmodes. Ferromagnetic insert experiments in JFT-2M showed reduction of ripple loss of NB ions reduced by a factor of two.

In JT-60U, the plasma was almost fully sustained (92%) by non-inductive currents with 350 keV negative ion neutral beam injection leading to a current drive efficiency of 1.3×10^{19} A.m^{-2}/W, in good agreement with the predictions of the ACCOME code.

***Transport and Internal Barrier Physics (M. Wakatani*)**
Although significant progress has been achieved in obtaining and sustaining ITBs in current experiments, projections of such regimes to the reactor conditions cannot yet be done reliably. The role of the external toroidal momentum input in the ITB formation remains unclear. Although ion thermal transport can be reduced to neoclassical level within ITBs, the electron transport in some cases remains anomalous. All high performance discharges with ITBs obtained so far have relatively low plasma densities, $n_e \leq 0.5\ n_{GW}$ while $n_e \sim n_{GW}$ will be required in a reactor. Theories are emerging for ITB formation, suppression of ITG and ETG turbulence in negative magnetic shear, and suppression of turbulence by zonal flow.

***Confinement Database and Modeling (J. G. Cordey*)**
The threshold database has been updated with recent data from C-mod and JT-60U, the latter using the W-shaped divertor. The new scaling law predicts a factor of two lower threshold power for ITER-FEAT parameters.

A new database has been assembled to form DB3 v8. This includes all the JET DT data, new data from AUG and COMPASS, and data from the Canadian Tokamak TdeV. The prediction by IPB99(y,2) is 3.8s for ITER-FEAT, while 3.7s by IPB98(y,2). The DB3 v8 contains many data with small degradation in confinement at high Greenwald numbers. There have been extensive discussions on 'probability' to obtain a Q value of at least 10.

Reports by the Designated Physics Persons
Designated Physics Persons reported their Parties' research plans for 2000, which supported the research goals proposed by the Expert Group.

Discussion of 2000 Research Priorities and Charge to Expert Groups
High Priority physics research areas proposed from the Expert Groups are listed in the Table (next page), which includes those identified as Urgent Physics Areas (marked in bold).

URGENT (BOLD) AND HIGH PRIORITY PHYSICS RESEARCH AREAS

Research Areas	Issues
Finite-β effects	**Tolerable ELMs (dW/W<2%) with good confinement alternate to type-I ELMs** (e.g. type II, Type III+core confinement) **Stabilisation of neoclassical islands** and recovery of β
Plasma termination and halo currents	**Runaway electron currents:** production and **quenching, e.g. at low safety factor**
SOL and divertor	Achievement of high n_{sep} and relation of $n_{sep}/\langle n_e \rangle$ in ELMy H-modes Carbone chemical sputtering and deuterium retention/cleaning methods
Diagnostics	Determine requirements for q(r) and assess possible methods that can be applied to ITER Determine life-time of plasma facing mirrors and optical elements (including those in divertor) Reassessment of measurement requirements in divertor region + recommendation of diagnostic techniques
Core confinement	Non-dimensional scaling and identity experiments; effect of finite β and flow shear Determine dependence of τ_E on shaping, density peaking etc.
Internal transport barrier properties	ITB power thresholds vs n, B, q, T_e/T_i, V rotation etc. for strong reversed shear (q_{min}>3), moderate reversed shear(q_{min}>2), and weak shear (q_{min}>1).
H-mode power threshold	H-mode accessibility in ITER-FEAT , Data scatter
Density limit physics	Confinement degradation onset density; its dependence on aspect ratio, shape and neutral source
Pedestal physics	Scaling of pedestal properties and ELMs Effects of plasma shape on pedestal and ELMs

Urgent: Essential to confirm the feasibility of the inductive Q=10 scenario for the draft Final Design Report of ITER-FEAT at the end of 2000

High: Information valuable for design of ITER-FEAT, especially for establishing a scenario for steady-state operation of ITER-FEAT

The proposed Charge to Expert Groups for 2000 was agreed upon as follows:

1. Bring important new results achieved in the Parties' Base Programmes to the JCT's attention.
2. Evaluate and document, from the ITER perspective, scientific progress regarding the Research Priorities and provide an annual written report to the ITER Physics Committee. Arrange for a wide distribution of this report within their area of expertise.
3. Identify and formulate Research Priorities for Physics R&D in support of the ITER-FEAT design to be endorsed by the ITER Physics Committee.
4. Act to communicate the importance the 2000 ITER Physics Research Priorities to their respective Parties and fusion research establishments.
5. Assist JCT via recommending physics basis and methodologies for physics design calculations to be used for ITER-FEAT.
6. Issue Meeting Minutes to be distributed among ITER community with a succinct Executive Summary appropriate for unlimited distribution.

LIST OF PARTICIPANTS

CHAIR: R. Aymar, **CO-CHAIR:** M. Shimada
EU: D. Campbell, G. Cordey, T. Donné, C. Gormezano, O. Gruber, K. Lackner, A. Loarte
RF: Y. Dnestrovski, N. Ivanov, S. Mirnov
JA: N. Asakura, Y. Kamada, K. Miyamoto, H. Ninomiya, T. Tamano, M. Wakatani, R. Yoshino
JCT: A. Costley, Y. Gribov, G. Janeschitz, V. Mukhovatov, Y. Shimomura

IAEA AND IEA ROLES IN INTERNATIONAL FUSION ENERGY RESEARCH

by Drs. T. Dolan, IAEA, and K. Nakamura, IEA *)

The International Atomic Energy Agency (IAEA) of the United Nations (Vienna) and the International Energy Agency (IEA) of the Organization of Economic Cooperation and Development (Paris) each have specific areas of considerable experience in promoting international cooperation, and both are held in high regard for their contributions to the international fusion energy program. While each Agency's program arose from a different imperative, fusion research has been an important element of both programs since each Agency's inception, and these roles are complementary.

The IEA has been engaged in international fusion energy research cooperation since its inception in 1974, and the IAEA since its inception in 1957. The fusion work carried out under each Agency has been evolving to the present point and can well continue to evolve as the needs of the participating Member States change. Consequently, the following characterizations, containing both common abilities and unique strengths, describe current activities rather than limiting any future possibilities.

The current activities of the two Agencies involve research collaborations, technical meetings, publications, and public information; each is guided by an advisory body. These activities are compared in Table 1. Both Agencies publish technical reports and public information literature. Both Agencies organize research collaborations and technical meetings, but the nature of the collaborations and meetings differ.

The IEA research collaborations usually involve implementing agreements on major advanced research activities among several laboratories, involving large budgets, for which a legal framework is needed. The IAEA research collaborations are currently of two kinds: the ITER collaboration, an independent, very substantial activity for which the IAEA provides limited support; and Coordinated Research Projects (CRPs), which involve numerous laboratories from both advanced and developing countries. Thus, the IEA currently deals more with large, high-budget projects involving a few countries, and the IAEA, except for ITER, deals more with lower-budget projects involving many countries.

In the area of technical meetings, the IEA organizes workshops focused on specific areas of interest to their members, such as fusion materials, large tokamaks, remote participation, and energy technology availability. The IAEA organizes the biennial Fusion Energy Conference, which attracts 600-800 participants from over 30 countries, and 4-6 Technical Committee Meetings each year on a wide variety of topics. The technical meetings organized by the two Agencies are complementary, not competitive. In an area where the interests of the two Agencies partially overlap, such as Remote Participation, the two Agencies jointly sponsored a meeting in 1999.

Some unique fusion activities associated with the IEA are:

- actual hardware based collaborations
- large projects involving significant resources, such as the *International Fusion Materials Irradiation Facility*
- certain coordination initiatives, such as Remote Participation,
- provision of a forum for broad programmatic discussions, development of action plans for collective work, and information exchange among senior program leaders (Fusion Power Co-ordinating Committee, FPCC).

Some unique fusion activities associated with the IAEA are:

- provision of nuclear, atomic, molecular, and plasma-material interaction data
- biennial Fusion Energy Conference
- *Nuclear Fusion* journal; *World Survey of Activities in Controlled Fusion Research*, and IFRC *Status of Fusion Reports.*
- promotion of international cooperation by developing countries with each other and with advanced countries
- provision of aid to developing countries, such as travel grants and Technical Cooperation projects (equipment grants, fellowships, expert visits)
- provision of auspices for and other support to ITER.

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While both Agencies are engaged in facilitating fusion research internationally, there are some differences in how they operate.

The IAEA activities are developed and implemented by Agency staff, taking into consideration advice from the International Fusion Research Council (IFRC). While the program of work under IEA auspices is formally under Agency direction, the actual work tasks are undertaken under the authority of legal agreements among the Parties. The IEA Executive Committees represent the authority for each agreed-upon task. Thus, the IEA staff has less authority over IEA programs than the IAEA staff has over IAEA fusion programs.

The IAEA has a large number of members with a very broad range of foreign and domestic policy positions while the IEA has a smaller number with a narrower range of both policy views. Further, the IAEA has more professional staff in the fusion research area than the IEA, and the structure for decision-making reflects this difference.

In order to avoid duplication of activities, the IEA and IAEA staff members communicate with each other periodically and attend the planning meetings (IFRC and FPCC meetings) of the other organization. Some of the IFRC members are also FPCC members, which further helps with coordination. Technical meetings of interest to both agencies, such as on Remote Participation and on fusion technology, may be jointly sponsored. Research topics of interest to both agencies could also be coordinated so that the strengths of each Agency could be used effectively. For example, if an IAEA Coordinated Research Project evolved towards a large joint experiment, then the parties involved might wish to consider the formation of an IEA implementing agreement.

Summary

The IAEA and IEA play complementary roles in facilitating international fusion research cooperation. These roles represent highly desirable contributions to fusion research through the pooling of limited human and financial resources. The two Agencies both coordinate research and organize technical meetings, but in different ways. They each have unique strengths and different modes of operation. In order to deal with potential overlaps and serve the fusion research community optimally, they are coordinating their activities.

Acknowledgement

Helpful comments were received from members of the FPCC and IFRC, especially from FPCC Chair Michael Roberts, who initiated this comparison.

IAEA and IEA Activities in Fusion Research

Activity	IEA	IAEA
Research collaborations	Implementing agreements • Three large tokamak facilities • Toroidal physics in, and plasma technologies of, tokamaks with poloidal field divertors • Plasma wall interaction in TEXTOR • Stellarator concept • Reversed field pinches • Fusion materials, with conceptual design study of International Fusion Materials Irradiation Facility • Nuclear technology of fusion reactors, with conceptual design study of high-volume plasma-based neutron source • Environmental, safety and economic aspects of fusion power • Inertial fusion energy (under development).	• Coordinated research projects (CRP). · Plasma heating & diagnostics in developing countries · Applications of plasma physics & fusion technology · Comparison of compact toroid configurations · Activation cross sections for fusion technology · Radiative cooling rates of fusion plasma impurities · Atomic & plasma-wall interaction data for fusion reactor divertor modelling · Molecular data for plasma edge studies • Provision of auspices for ITER and assistance in publishing, joint fund management, hosting meetings, etc. • Proposed Research and Development Cooperation Programme (RDCP),

	• Other collaborations may be developed in the future, as desired by Member States. The IEA implementing agreements are usually hardware-based collaborations on unique experiments, common programs, or conceptual design studies, initiated by member countries. They involve 2-6 countries, which contribute substantially to the research. The IEA implementing agreements provide a legal framework and have involved major laboratories in major fields of research. The IEA is now encouraging participation by non-member countries.	• Other collaborations may be developed in the future, as desired by Member States. The IAEA CRPs usually have lower budgets, little associated hardware, and 8-16 countries involved. The exceptions are ITER, a major collaboration that functions independently, and the RDCP, which is not yet implemented. The IAEA collaborations are especially helpful to developing countries. [Some CRPs and technical meetings are initiated by suggestions from Member States, and some by IAEA staff members, in consultation with the IFRC.]
Technical meetings	• Remote participation Working Group and workshops • Fusion Materials Strategy and Planning Workshop • Workshops on three large tokamak cooperation • Other workshops are planned in the frame of IEA Fusion Power related Implementing Agreements • Workshop on Energy Technology Availability • OECD Megascience Forum	• Biennial Fusion Energy Conference • Advisory group meeting on enhancement of plasma research in non-ITER countries • Technical Committee Meetings (TCM) · Research using small fusion devices · Innovative approaches to fusion · Spherical tori · H Mode physics · Drivers & ignition facilities for inertial fusion · Steady state tokamak operations · Alpha particle physics · Data acquisition & management · Fusion reactor design & technology • Consultant meetings, such as on inertial fusion
Studies of Energy Scenarios	"The World Energy Outlook 1999 Insights"	Conducted in the Planning and Economics Section of the Division of Nuclear Power.
Publications	• Energy Policies of IEA Countries 1999 Review • International Collaboration in Energy Technology: A Sampling of Success Stories (1999 IEA) • Energy Technologies for the 21st Century (1997 IEA) • Energy Technology Availability to Mitigate Future Greenhouse Gas Emissions (1997 IEA) • Under each of the IEA Implementing Agreements annual technical progress reports and technical documents are issued.	• book *Energy from Inertial Fusion* • journal *Nuclear Fusion* • *World Survey of Activities in Controlled Fusion Research* • Proceedings of IAEA TCM in technical journals • *Research Using Small Tokamaks*, IAEA-TECDOC-969 • ITER documents (design reports, Council proceedings, Newsletter, etc.) • Periodic report on status of fusion research by the IFRC (1990, 2001) • Inertial Fusion Energy Research, IAEA-TECDOC-1136
Public Information & Service	IEA Internet Home-Page IEA Energy Technology and R&D (Brochures)	*Physics Activities* brochure (Brochures are also published by ITER) Internet Home Page. Provision of nuclear, atomic, molecular, and plasma-material interaction data.

Aid to developing countries	Some Non-Member countries participate in the Implementing Agreements.	Technical co-operation projects (fellowships, expert visits, equipment grants)
Guiding bodies	FPCC meets annually. Programmatic discussions among senior program leaders and recommendations to the IEA. Large delegations of high-ranking people attend.	IFRC meets annually. Information exchange and recommendations to the IAEA. Senior scientists & program leaders.
Comparison of Guiding bodies	The IFRC and FPCC are similar groups with some common members. Recently they have been working towards closer co-ordination of IEA and IAEA fusion research activities and participating in each other's meetings.	
Governing Bodies	IEA Governing Board (24 Member Countries), Committee on Energy Research and Technology (CERT)	IAEA General Conference (130 Member States), which meets annually and IAEA Board of Governors, which meets 4 times per year.
Agency full-time equivalent professional staff dealing with fusion	Head, Energy Technology Collaboration Division: part-time Principal Administrator: 1	≈ 4.3
websites	http://www.iea.org	http://www.iaea.org/worldatom/

Items to be considered for inclusion in the ITER Newsletter should be submitted to B. Kuvshinnikov, ITER Office, IAEA, Wagramer .Strasse 5, P.O. Box 100, A-1400 Vienna, Austria, or Facsimile: +43 1 2633832, or e-mail: c.basaldella@iaea.org (phone +43 1 260026392).

Printed by the IAEA in Austria
June 2000