EFDA EUROPEAN FUSION DEVELOPMENT AGREEMENT JET

EFDA-JET Bulletin

December 2006

Message of the EFDA Associate Leader for JET

As 2006 comes to an end, I want to thank everybody for all their valuable contributions and commitment to JET. We have had some difficulties in the recent past but have been able to overcome these problems, restart JET operations and are now achieving significant performance.

In addition, the JET enhancement programme has made a huge step forward with the final approval of the procurement budget.

All this is of particular importance in this crucial year for fusion research, with the signing of the ITER agreement and the interest this has caused.

I wish everybody a prosperous 2007 and all the best for you and your families.

Dr Francesco Romanelli

2006 highlights

This year has been marked with further important developments related to ITER, JET and to fusion research in general.

JET concluded a major shutdown and launched the C15 campaign on 24th April. After unplanned intervention in the summer due to a vacuum leak, the C16 campaign started on 25th September, followed by C17 campaign on 23rd October. Both recent campaigns obtained good results (see page 2 and 3 of this Bulletin) also due to good availability and performance of the main supporting systems (auxiliary heating and diagnostics). During Campaign C17, the number (132) of pulses with high Neutral Beam power (>20MW) in 2006 far exceeded that in previous years, and represented two-thirds of the total number of such discharges since operations with the pumped divertor began in 1994. The maximum Neutral Beam power in 2006 was 22.9 MW for 3 seconds, again setting a new JET record. Together with the LHCD and ICRH systems a maximum power above 31 MW was coupled to the JET plasma.

At the end of May the new ITER-like ICRH (Ion Cyclotron Resonant Heating) Antenna was delivered to JET and it is currently being inspected and tested prior to installation in the JET Torus. The decision for the next major enhancement of JET, including the ITER-like wall installation and neutral beam heating upgrade, was finalized and the procurement of the major items was started.

Since October, JET's scientists have also gained access to the EGEE Grid - the largest computer grid infrastructure in the world (see www.eu-egee.org). With over 30.000 processors and 50 million Gigabytes of data storage, the EGEE grid allows scientists access to significantly more computing power than is available at a single laboratory.

The new teleconferencing facilities in the JET Control Room have allowed experts to participate remotely in the experiments, with routine participation from EFDA Garching, and remote sessions including the U.S. Oak Ridge National Laboratories.

Many important fusion activities have been carried out all over the world this year: for example, on 26th September our Chinese colleagues announced the first plasma in the fully superconducting tokamak EAST in Hefei.

For the international fusion community, 2006 culminated on 21st November, when Ministers from the seven ITER Parties met at the Elysée Palace in Paris to sign the agreement establishing the international Organisation that will implement the ITER project. The setting up of the ITER organization and of the European Legal Entity* will allow a rapid development of the fusion activities towards the final objectives of developing a fusion power plant. JET has proved its potential to further contribute to the process and to foster the necessary expertise.

*The European Legal Entity will be a European Joint Undertaking for ITER called "Fusion for Energy".

ITER signature in Paris on 21st November

On 25th September 2006, experiments resumed on JET, with the start of Experimental Campaign C16 of the EFDA-JET 2006 Workprogramme. After successful completion of this Campaign on 13th October 2006, Campaign C17 began on 23rd October 2006, and was completed on 15th December 2006.

In these Campaigns a strong focus was maintained on the preparation of the ITER detailed design and ITER exploitation, including preparation for the planned change of the wall/divertor materials on JET.

In the ELMy H-mode the effect of the X-point position on the L-H transition threshold was studied with the new divertor. Studies of the L-H transition concentrated on the location of the X-point, and measurement of the radial electric field and poloidal velocity with the upgraded charge exchange recombination spectroscopy diagnostic, see Figure 1. Plasma-wall compatibility on ITER may require the ITER plasma to be surrounded by a radiating zone, which could be produced by impurity injection. The plasma current at which production of such a zone has been studied with nitrogen injection, was extended to 3 MA. It is important that impurities injected for this purpose should not accumulate to high levels in the plasma core and degrade core confinement. To understand impurity transport, systematic studies were conducted with injection of low to high Z impurities within the same discharge. These experiments will also be useful to understand transport of ITER first-wall materials into the plasma.

Studies of material erosion, migration and retention constituted another major theme. A fuel balance and retention study was conducted with cryopump regeneration before and after a series of RF-heated H-mode plasmas. Beryllium and carbon erosion and migration were studied in experiments with dedicated beryllium evaporations, using spectroscopy and quartz microbalances, and the effect of nitrogen seeding on carbon deposition was assessed in H– and L-mode in a range of plasma configurations. Other studies in the ELMy H-mode included exploration of small (convective) Edge Localised Modes (ELMs) in wider parameter space (high and low triangularity, and q_{95} between 3.5 and 5.5); the effect of changing the q profile on density peaking, at ITER-relevant collisionality; and momentum transport with modulated Neutral Beam (NB) injection, to improve predictions of the rotation profile on ITER and its effect on transport.

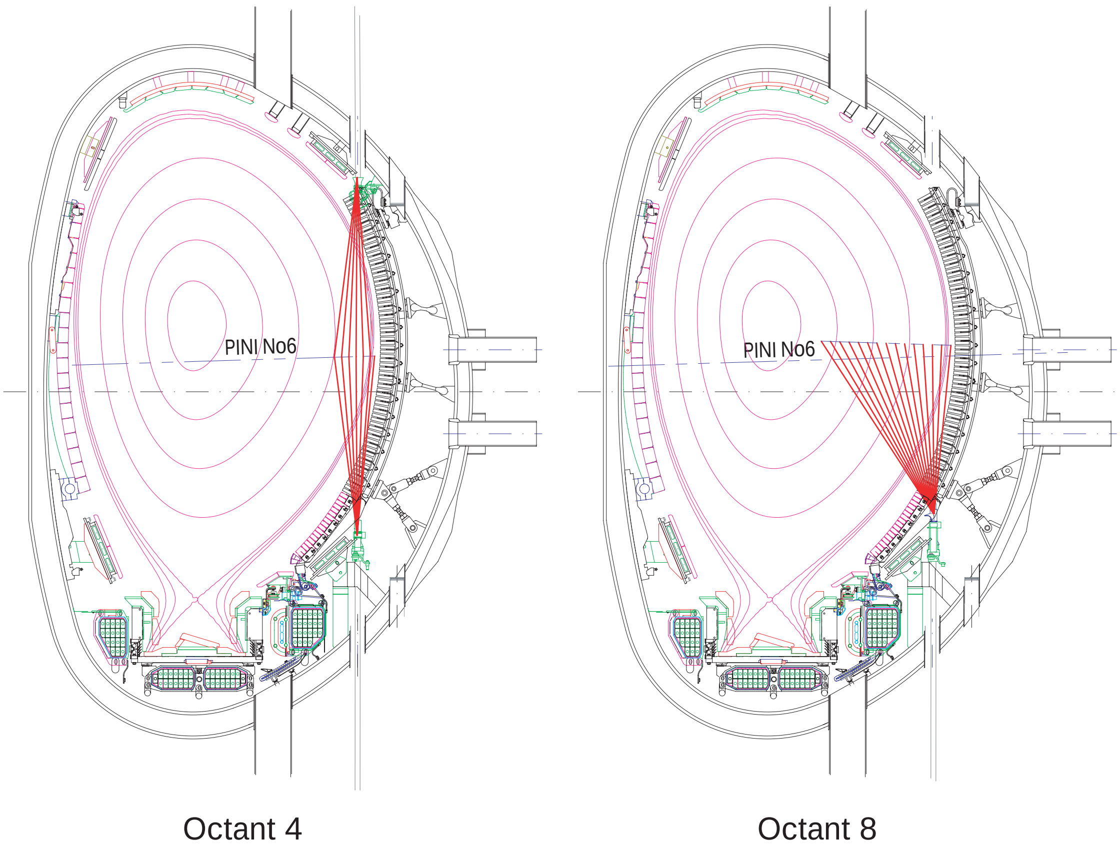

Figure 1: Sight lines of the upgraded Charge Exchange Recombination Spectroscopy diagnostic (CXRS). With respect to the previous system, the upgraded system has higher spatial and temporal resolution, and sight lines (in red) in Octant 4 are up-down symmetric, for improved poloidal rotation measurements.

Work on the Hybrid Mode was aimed at porting this scenario closer to ITER (towards an ITER-like edge safety factor q, higher confinement, higher beta, higher density and smaller ELMs). This mode of operation was also compared with the ELMy H-mode, the baseline scenario for ITER, including the impact of a radiative edge on confinement.

Advanced Tokamak (AT) Scenarios were studied at high triangularity, which can be reached with the new divertor. These studies employed high power (31MW) and ELM control by controlling edge radiation using neon injection. In addition, high beta AT discharges were studied in a quasi-double-null configuration where ELMs are naturally mild, as on ASDEX Upgrade. Significant effort was also devoted to integrated control of the current and pressure profiles, for a robust AT regime with high bootstrap current and a strong Internal Transport Barrier (ITB). The damping mechanisms of the Resistive Wall Mode (RWM) in high beta AT discharges were studied by measuring the response of the plasma to applied n=1 and n=2 magnetic perturbations. RWMs are unstable at high beta and low plasma rotation, conditions which are expected in ITER Advanced Scenarios. Insights from the new JET data may allow improved predictions of RWM behaviour in ITER AT Scenarios, and are expected to be valuable for the assessment/development of RWM control systems for ITER.

The potential for mitigating Type I ELMs with externally applied magnetic perturbations is also under study on JET in the ELMy H-mode and AT Scenarios. The technique was shown to be effective on DIII-D, without degradation of pedestal profiles or core confinement, when a resonant n=3 magnetic perturbation was applied. On JET the Error Field Correction Coils (see Figure 2), capable of producing an n=1 or n=2 magnetic perturbation, were used in similar studies, in the ELMy H-mode and AT scenarios.

Several new diagnostics for burning plasma physics were also tested successfully. These include Extreme Ultraviolet (XUV) spectroscopy for the detection of alpha particles at energies below 500keV, a new set of Toroidal Alfvén Eigemmode (TAE) antennas for measurement of TAE damping rates, and a scintillator probe and Faraday cups for measurement of fast particle losses.

In ITER a relatively large gap will be required between the plasma and first-wall components. This poses a problem for coupling of Lower Hybrid (LH) and Ion Cyclotron Resonance Heating (ICRH), across a plasma-antenna gap foreseen at ~15cm. During Campaigns C16 and C17 studies were conducted on JET in which an ITER-like separation was maintained between the plasma and the LH and ICRH antennas, and gas was injected close to the antennas in order to improve plasma-antenna coupling.

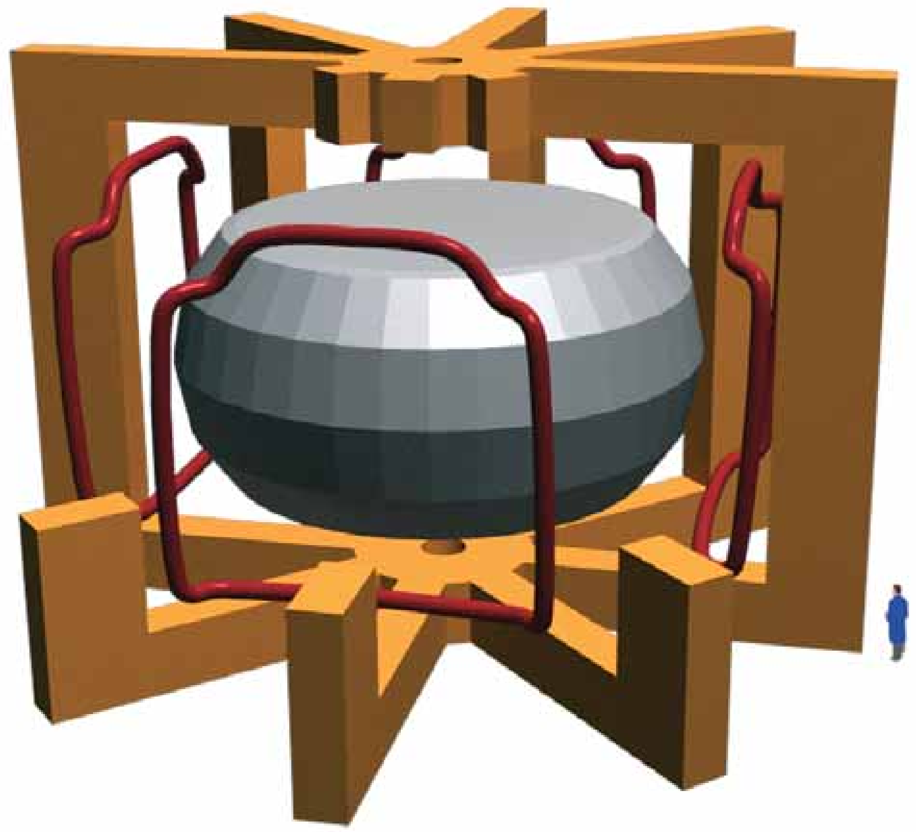

Figure 2: Error Field Correction Coils (EFCCs) (in red), positioned outside the JET vessel. The main purpose of these coils is to compensate n=1 error fields arising from small misalignments of the poloidal field coil sytem on JET with respect to the toroidal field. In addition, the EFCCs can be used to study ELM suppression. Depending on the relative phasing of the currents in individual coils, either n=1 or n=2 fields can be generated.

Finpro visit to Culham

Five members of the Finpro's Big Science Project Team (see http://www.finprolive.fi/index.php?22) from Finland visited Culham on the 12-13 October 2006. The visitors were given an overview of the JET programme and shown round the experimental facilities including the Remote Handling area and the JET Torus Hall.

The Finpro team also visited the Mega Amp Spherical Tokamak (MAST). A round table discussion then took place where examples of best practices were exchanged to establish how the industry team can help form consortia between UK and Finnish Companies and how to try and identify opportunities whereby companies from the UK and Finland could collaborate to help deliver goods/services to ITER. "Finpro's visit was well timed and we look forward to working with them" said Dan Mistry, UKAEA Fusion and Industry Manager.

A screen grab from the BBC Newsnight

JET in the media

The signature of the ITER agreement on 21st November in Paris triggered an extraordinary interest of media in JET, including several TV broadcasts. The UKAEA Fusion Programme Director Sir Chris Llewellyn Smith was interviewed live on BBC Newsnight, and the JET Operations Director Dr Frank Briscoe was filmed for BBC Newsnight, ITV Central News and Sky News. Other media interest in JET included: BBC World, three BBC radio channels, ABC Australia, national press (Telegraph, The Independent, Daily Mail) and the Nature Magazine.

Visit of Danish industrial delegation

A delegation of six managers from Danish industrial companies involved in fusion research and/or interested in tenders for ITER visited JET on 24th November. Their visit was accompanied by Jens Ramskov, Science Editor from the "Ingeniøren" news magazine, and two research scientists form the Risø National Laboratory in Roskilde, Denmark.

After a short presentation the JET guests toured the JET facilities, including the Torus Hall, Remote Handling and Flywheel generators. In the afternoon, JET engineers explained in detail the JET technologies and procedures including power supplies, water cooling, vacuum systems, control and data acquisition systems, active gas handling, cryoplant, and waste management. The visit was concluded by a long and absorbing round table discussion.

Danish visitors together with JET experts

Close Support Unit in Culham

During the last three months the CSU at Culham has welcomed the following appointments: Dr. Emilia Genangeli and Prof. Vincenzo Coccorese, both from ENEA Frascati, to the Administration and Enhancement Departments, respectively, and Dr. Maximos Tsalas from the Hellenic Republic joined the Programme Department.

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