# 4 INTERNATIONAL COLLABORATIONS

The research activities in magnetically confined fusion plasmas are conducted at both national and international levels. International collaboration is concentrated on two major activities, the exploitation of the European JET tokamak and the design of the planned ITER tokamak. As well as these two major activities, a general exchange of personnel between laboratories contributes enormously to the international flavour of this research. The CRPP plays a role both as host institution and sending institution for such bilateral exchanges. The international activities of the CRPP are summarised in the following paragraphs.

## *4.1 JET*

We took part in the analysis of the Li beam diagnostic used for measurements of the scrape off layer density profile. This was a continuation of previous work in JET.

A semi-empirical equation was proposed to simulate the time evolution of the neo-classical tearing mode width, was successfully used to describe results from DIII-D and needed confirmation on another tokamak. Using the same coefficients, kept to within 30%, we were able to model a JET case correctly. However as there are still several free parameters, a more systematic study was needed to determine these parameters experimentally with greater precision. For this reason, a Task Agreement between JET and CRPP was implemented for 1999. In this framework, we collaborated in the Spring 1999 campaign of JET on neo-classical tearing modes. This work has already enabled us to simulate a few more cases correctly, one of which is shown in Fig.4.1.1.

***Fig.4.1.1*** ***Time evolution of the magnetic signal associated with a 3/2 NTM in JET (n=2 data). The simulation agrees well with the measured data if a stabilising term is taken into account.***

On the 1st January 2000, the management of the JET facilities was totally modified. One physicist from CRPP has been seconded from the CRPP full-time to the close support unit (CSU) of the JET-EFDA Associate Leader to contribute to the management of the EFDA-JET 2000-2002 programme. He has already been working at the JET site since September 1, 1999. Another member of the CRPP was selected as Task Force Leader for the MHD Task Force and will be in charge of co-ordinating the scientific work and experiments related to MHD for the campaigns at JET in 2000 and Spring 2001. The CRPP organised a JET workshop in March 1999 on the prospects of MHD and Neo-classical tearing mode studies related to the JET facilities.

## *4.2 ITER design tasks and voluntary R&D*

**Titanium irradiation testing** (ITER TASK BL14.2)
The ITER first wall modules are attached to the vacuum vessel by four radial flexibles. The flexibles are located behind the plasma and will receive a high neutron and mechanical loading. These parts will be fabricated from titanium. At CRPP we have tested Ti5AL2.4Sn and Ti6Al 4V before and after irradiation and the detailed results are given in section 2.3.4

**Interferometry and polarimetry** (voluntary R&D)
Work has proceeded on calculations of predicted Faraday rotation angles as contribution to the design of this ITER diagnostic.

**Amplitude of Sawteeth as a function of plasma shape with central additional heating** (voluntary R&D)
To answer to the question whether "there is evidence of an increasing effect of sawtooth activity with increased shaping (e.g. via an expansion of the sawtooth inversion radius)", we performed experiments varying elongation $\kappa$ and triangularity $\delta$ in a large range ($1.1<\kappa<2.1$, $-0.5<\delta<0.5$), keeping the ECH power deposition inside $q=1$ to avoid $q=1$ stabilisation effects. To retain only the effect of shape in these experiments, the normalised $q=1$ radius was kept while shaping, increasing $q$ within a limited range, $2.5<q<3.5$, with increased elongation. In these conditions, sawteeth are found to be small with short periods at high elongation and negative triangularity. For these shapes, additional central ECH power further decreases the sawtooth period. This shape dependence of sawtooth stability is shown to be determined by the role of ideal or resistive MHD in triggering the sawtooth crash. Shaping may therefore be an interesting means to avoid sawteeth of large size and indicates a potential to avoid the triggering of neoclassical tearing modes.

**Scaling of sawtooth inversion radius in shaped plasmas** (voluntary R&D)
This study, based on a large variety of Ohmic L-modes in TCV was made available to ITER during 1999, resulted in the following conclusions:

- A robust scaling parameter has been found to replace $q_a$ in shaped discharges:
  Inversion radius scaling is consistent with simple and robust physics ($q(0)\approx 1$ and neoclassical resistivity) in wide variety of Ohmic discharges.

- Scaling from TCV should be useful for the ITER design. In particular, the somewhat arbitrary criterion, $q_{95}$=3, should be replaced by a criterion that the sawtooth inversion radius should not exceed a certain fraction of the minor radius.
- Much of the current carrying capacity due to elongation is retained (~90%), even when scaling at fixed value of rinv.
- Although the original scaling was expressed in its natural physics parameters, it has been translated into conventional parameters ($q_{95}$, kappa, delta) for the convenience of ITER.

## *4.3 Collaborations with other EURATOM Associations*

**Prof. Joseph Bakos**, ***KFKI Budapest, Hungary,*** "Impurity transport using Laser ablation on TCV"

**Prof. Ettore Minardi**, ***Assoc. Euratom CNR, Milano, Italy***, "Comparison of predictions of stationary magnetic entropy based theory with TCV data".

**Dr. V. Piffl**, ***IPP Prague, Czech Republic***, "Collaboration on ultrasoft X-ray spectroscopy"

**Prof. F. Porcelli**, ***Politecnico di Torino, Torino, Italy***, "Non-Standard Sawteeth in the presence of powerful localised heating"

**Dr. Y. Peysson, L. Delpech**, ***CEN-Cadarache, St.-Paul-Lez-Durance, France,*** "Measurement of Hard X-ray spectra with a hard X-ray camera"

**Dr. T.C. Hender, Dr. D.C. Robinson, Dr. T.N. Todd, Dr. S. Allfrey**, ***Culham Laboratories, UKAEA, UK***, "Spherical Tokamak/Sphellamak hybrid configuration studies"

## *4.4 Other international collaborations*

**Dr. V.E. Lukash**, ***RRC Kurchatov, Institute of Nuclear Fusion, Moscow,Russia and*** **Dr. R.R. Khayrutdinov**, ***TRINITI, Troitsk, Russia***, "Simulation of TCV plasma control experiments using the non-linear DINA code"

**Dr. R. Yoshino, Dr. Y. Nakamura,** ***Naka Fusion Research Establishment, JAERI, Japan***, **Prof. D.J. Limebeer, Dr. J. Wainwright, A. Sharma,** ***Imperial College of Science Technology and Medecine, U. London, UK***. "Development of a plasma response model for JT-60U".

**Dr. Y. Nakamura and Dr. R. Yoshino**, ***Naka Fusion Research Establishment, JAERI, Japan***, "Disruption dynamics in shaped tokamaks and the plasma equilibrium response of the JT-60U tokamak"

**Dr. Alexej Sushkov**, ***RRC Kurchatov, Institute of Nuclear Fusion, Moscow,Russia*** "Implementation of multiwire proportional x-ray detector for high sensitivity, high speed, high time resolution measurements during ECH on TCV"

**Dr. K.A. Razumova, Dr. A.V. Sushkov, Dr. V.F. Andreev, Dr. N.A. Kirneva**, ***RRC Kurchatov, Institute of Nuclear Fusion, Moscow***, "Modelling of ECRH and ECCD: 1) Software development for the determination of the power deposition and transport coefficients from the soft X-ray measurements, 2) ECRH power deposition/coupling measurements with ASTRA transport code"

**Prof. V.D. Shafranov, Dr. M.Yu. Isaev, Dr. M.I. Mikhailov, Dr. A.A. Subbotin**, ***RRC Kurchatov, Institute of Nuclear Fusion, Moscow,Russia,*** "3D configuration optimisation studies and 3D ideal stability"

**Dr. S. Medvedev, Dr. A. Martynov**, ***Keldysh Institute of Applied Mathematics, Moscow, Russia,*** "3D equilibrium development based on 3D extension of Grad-Shafranov equation"

**Dr. A. Reiman, Dr. D.A. Monticello, Dr. G.Y. Fu, Dr. L.P. Ku, Dr. G.H. Neilson, Dr. M. Redi, Prof. R. Goldston**, ***Princeton Plasma Physics Laboratory, Princeton, USA,*** "External kink and ballooning stability of the NCSX quasiaxisymmetric stellarator"