# 7. PARTICIPATION IN THE TCV PROGRAMME[1]

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## 7.1. INTRODUCTION

The participation of Association EURATOM/IST in the TCV programme has been focused on the development and operation of:

- Pulse Height Analysis (PHA) X-ray diagnostics;
- A X-ray rotating crystal spectrometer;
- A new advanced plasma control system.

## 7.2. PULSE HEIGHT ANALYSIS X-RAY DIAGNOSTICS

### 7.2.1. Introduction

This research line has two main objectives:

- Development and operation of two PHA diagnostics, located respectively on an horizontal and a vertical port;
- Transformation of the vertical PHA diagnostic (VPHAD) in a real-time diagnostic by using a commercial CAMAC unit and a multi-DSP-based VME (RTPROV) system, specially developed by CFN for data acquisition, real-time parallel processing and feedback control.

### 7.2.2 Horizontal PHA diagnostic

The following main activities were carried out in 2003:

- Routine operation of the horizontal PHA diagnostic for the measurement of the electron temperature and analysis of the line radiation in the soft X-ray range from 1 to 10 keV;
- Adaptation of the Raymond-Smith code to the TCV conditions The results obtained with this code, which simulates the SXR emissions for certain plasma parameters and impurity content, have been compared with those obtained with the improved Maxwellian mathematical model;
- Refurbishment of the Matlab programs used for data analysis;
- Study of the old data using the refurbished Matlab programs, the algorithm developed for the VME module and the Raymond-Smith code;
- Development and testing of two new mathematical models (an improved Maxwellian and a Neoclassical model that accounts for diffusion phenomena inside the plasma bulk) aiming at finding the factors which induced the abnormal SXR distribution and account for the irregular behaviour of the *bremsstrahlung* tail, many times observed, both in old and more recent spectra. These two models have been also used to program two simulators, in MATLAB, and the results obtained experimentally were compared with the ones predicted by the simulation.

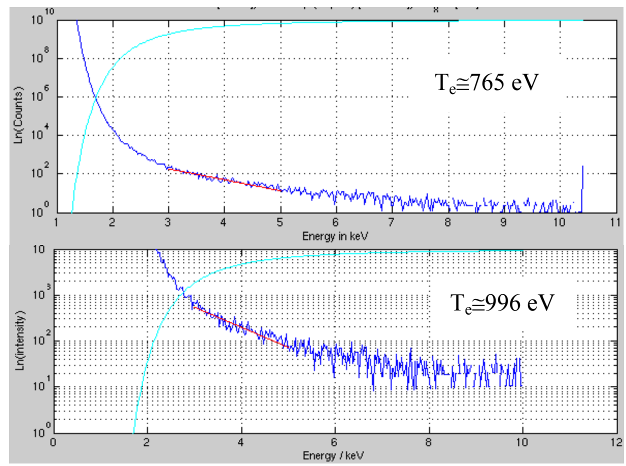


*Figure 7.1 – Results obtained assuming Maxwellian and improved Maxwellian behaviour of the plasma. The electron temperature calculated using the second assumption (996 eV) is comparable with that determined by Thomson scattering (958 eV).*

### 7.2.3. Vertical PHA diagnostic

*7.2.3.1. Introduction*

This project has been put forward to meet the need for high throughput, fast data acquisition and real-time data analysis capabilities. Figure 7.2 presents a block diagram of the diagnostic, which is described in the 2002 Annual Report.

The following main tasks were performed in 2003:

- Supervision of the vertical PHA diagnostic (VPHAD) project to make sure that all requirements were met;
- Provisional assembly of the VPHAD on TCV in order to allow the tests of two dedicated acquisition system, based on a commercial CAMAC unit and on the RTPROV board;

[1] Work carried out in collaboration with the TCV Team of the Association EURATOM/Confédération Suisse. Contact Person: Basil Duval.

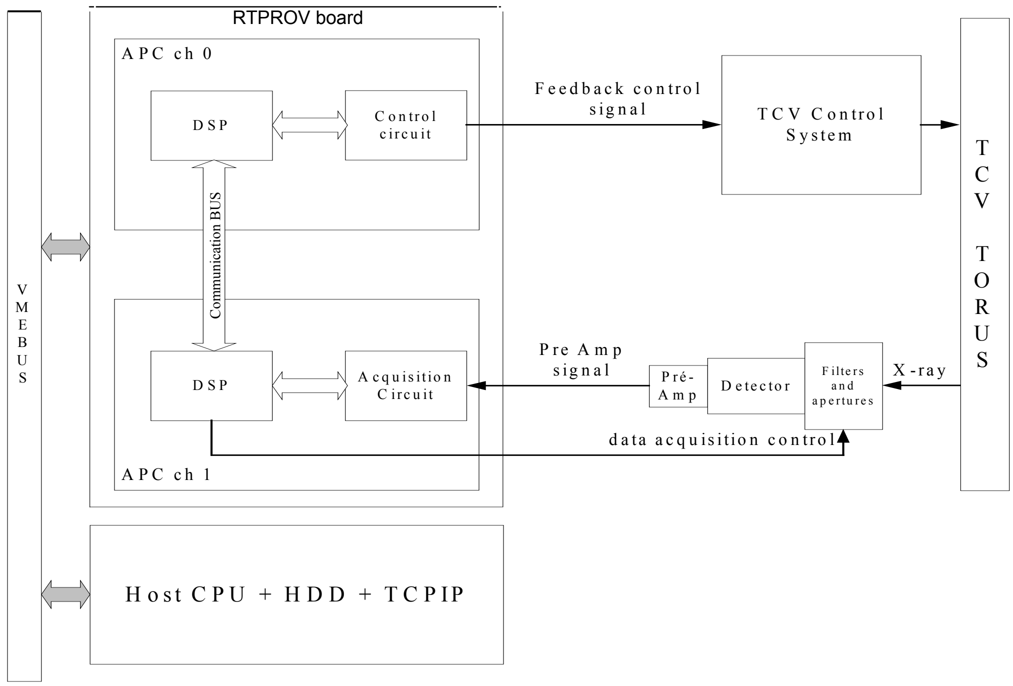


*Figure 7.2 – Block diagram of the vertical PHA diagnostic*

- Adaptation of the RTPROV hardware and software to the requirements of the PHA diagnostics;
- Development, testing and improvement of software at the VME host and DSP levels for the VPHAD, including the algorithm for the calculation of the electron temperature;
- Development and testing of software to integrate the PHAD data acquisition system into the TCV control and data acquisition system.

*7.2.3.2. Commercial CAMAC unit*

The commercial CAMAC unit (Figure 7.3) was optimized for X-ray spectra analysis and has four integrated basic sections: a front-end Analog Signal Conditioning (ASC); an ADC digitizing at 40 MHz; a digital *Fi*lter, *P*eak detector, *P*ile-up *I*nspector (FiPPI) to numerically filter the digitized signal stream and capture the X-ray events; and a DSP unit for pulse height analysis, data corrections, surveillance of the other sections (ASC and FiPPI) and communication with a host processor.

*7.2.3.3. Real-time multi-DSP-based VME system*

This CFN board (Figure 7.4) has four independent acquisition, processing and control channels, each one composed of: (i) one analog differential input for data acquisition with 12-bit resolution, +/- 5 V voltage range, independent software programmable sampling rate of up to 40 MSPS, and a FIFO memory of up to 32 kword; (ii) one 32-bit floating point DSP (TMS320C44) that can process up to 40 MIPS/80 MFLOPS; (iii) up to 128 kwords 32-bit wide SRAM for DSP program and data; (iv) one analog output for control with 14-bit resolution, +/- 5 V voltage range, independent software programmable update rate of up to 100 MSPS and a FIFO memory of up to 32 kword.

The application specially developed for this diagnostic performs seven main tasks: (i) data acquisition; (ii) pile-up inspection and data acquisition control; (iii) histogram construction, window correction and natural logarithm application; (iv) search for the histogram linear zone; (v) fit the data to a straight line and calculation of the plasma temperature; (vi) feedback control and remotely controllable X-ray PHA filters and apertures adjustment; and (vii) delivery of the acquired spectra to host CPU on the VME bus and so to the main TCV database.

These tasks are distributed by two of the four acquisition, processing and control (APC) channels. The first three tasks of the above list are implemented in one APC channel and the last four in the other one. The first four tasks are already tested and implemented. Essays of real-time calculation of plasma temperature has been initiated but is not yet fully tested.

## 7.3. X-RAY ROTATING CRYSTAL SPECTROMETER

This diagnostic, based on a twenty years old apparatus loaned by Princeton Plasma Physics Laboratory, was

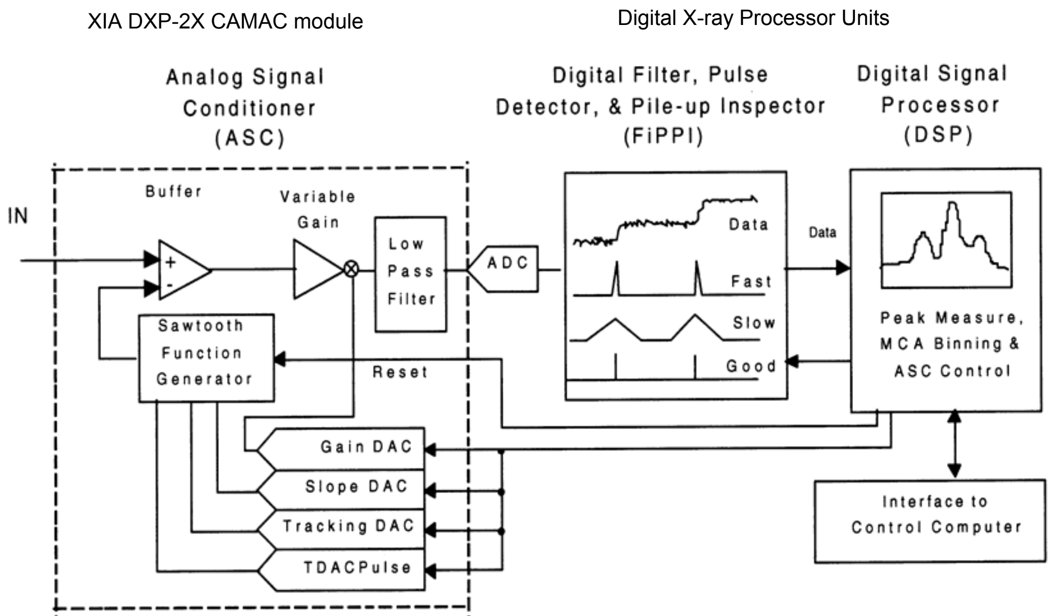


*Figure 7.3 – Block diagram showing the major functional sections*

envisaged to record the soft-X-ray line radiation from highly charged ions of low to medium Z elements from the hot core of the TCV plasma, along a horizontal line of observation. It would provide information on the central ion temperature, electron temperature and ion-charge state distribution from which the ionization equilibrium and ion transport might be deduced.

The following main activities were performed in 2003:

- Testing of the multi-channel plates (MCP) and vacuum conditions of the diagnostic;
- Intensive procurement of firms that could provide new crystals and MCPs with the required specifications at a reasonable price.
- Joint evaluation between CFN and CRPP about the best way to conduct the process of refurbishment of the rotating crystal spectrometer. A report has been submitted in December 2003 to the CFN and CRPP management.

## 7.4 ADVANCED PLASMA CONTROL SYSTEM

### 7.4.1. Introduction

This research line aims the development of a new real-time plasma control system, based on the CFN real-time parallel processing multi-DSP-based VME (RTPROV) board.

The following main activities were carried out in 2003:

- Conceptual design of the real-time plasma control system, in collaboration with the TCV Control Group;
- Improvement of RTPROV to meet the TCV requirements;
- Beginning of the commissioning and testing of fourteen RTPROV boards;
- Updating of the DSP operative system;
- Beginning of the development and testing of the DSP application software for the TCV plasma control;
- Development of Linux drivers to access the board by the VME master;
- Development of two new boards: (i) a digital input/output board (XIO) that brings digital inputs and outputs from the P2 connector of each RTPROV v1.1 to the front panel; and (ii) a bus board (DMBUS to be inserted behind the VME bus in the P2 connectors, enabling the broadcast data transfer from one board to all other boards in the VME bus that are configured to use the DMBUS protocol;
- Beginning of the development of the software interface for MDSPLUS graphics user interface as well as of the software needed to integrate this system in the main TCV control system.

### 7.4.2. System description

The new real-time system to control the TCV plasma consists of a VME crate where are inserted a commercial HOST CPU to interface the crate to the main data base and the following CFN-developed systems: nine RTPROV boards, a digital input/output board (XIO) and a bus board (DMBUS). Eight of the nine DSPs boards will run IIR algorithms at 10 kHz while the ninth board will run IIR algorithms at 200 kHz.

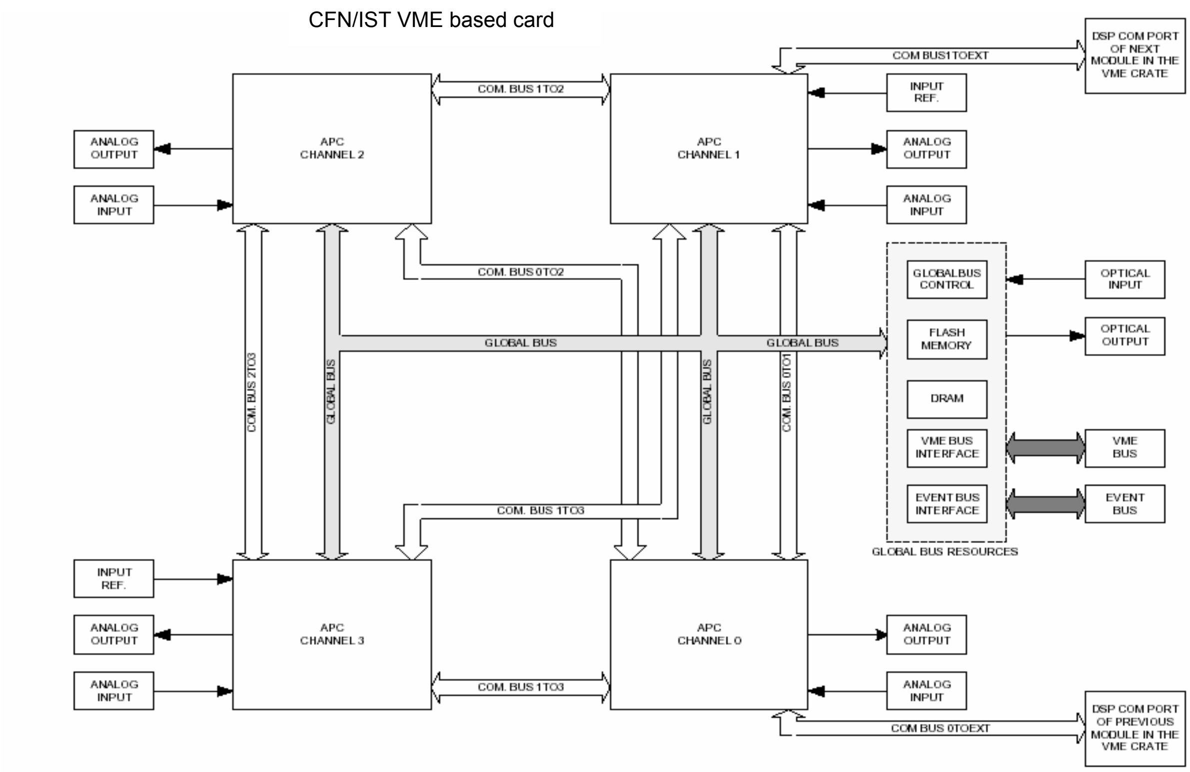


*Figure 7.4 – Block diagram showing the major functional section*

### 7.4.3. Improvements in the RTPROV module

The digital circuitry was redesigned and several new features have been added, namely:

- Increase of the clock frequency of the DSPs and of the VME transactions from 50 to 60 and 80 MHz respectively;
- Increase of the width of the command communication channel between DSPs and the VME master from 8 to 16 bits;
- Increase of the width of the inter-communication channel from DSP0 to DSP1 and DSP2 to DSP3 from 8 to 16 bits;
- Addition of up to 2 Mwords of 16 bits width to the global memory space;
- Addition of a better anti-aliasing filter in the analog input channel;
- Addition of 8 digital input/output in the front panel;