# COMPUTER CONTROLLED BEAM DIAGNOSTICS AT THE KARLSRUHE ISOCHRONOUS CYCLOTRON

W. Kappel, W. Karbstein, W. Kneis, J. Möllenbeck, D. Hartwig,+ G. Schatz, H. Schweickert

Institut für Angewandte Kernphysik/Zyklotron, Kernforschungszentrum Karlsruhe

## Abstract

A fast and easy to handle computer controlled beam diagnostics system is built up at the Karlsruhe Isochronous Cyclotron. The basic hardware consists of a mini-computer and a long parallel CAMAC branch-higway connecting the crates in the control room, the experiment hall and the cyclotron vault. The beam quality parameters can be measured using a display terminal in the control room and an interactive program. Settings of various parameters of the cyclotron and some external equipment are measured via CAMAC. The paper will briefly describe the present status of the system.

## 1. Introduction

Computerized control system are considered a standard equipment for many new big accelerators. For our comparativly small fixed energy isochronous cyclotron (52 MeV deuterons) the development of such a system was motivated by the following facts:

- In the last years the different users of the cyclotron require better and better defined beam quality parameters such as: small emittance, accurate knowledge of the absolute energy, small or large phase widths, extremely good suppression rates for the various beam pulsing systems, an enlarged beam diameter for the internal beam isotope production, higher intensities of the external beam, etc.
- Obviously the user demands cannot be fulfilled with one setting of machine parameters. Experience over many years of continuous operation has also shown that one cannot rely on special parameter settings to reproduce exactly the same beam quality (at least the ion source conditions are difficult to reproduce).

Therefore the operators have to adjust the machine parameters frequently for special user demands. To do this effectively the operator needs fast and reliable measurement of the parameters to be optimized. Our former beam diagnostic systems[1]) were not situable for this daily routine works. The reasons are:

- Before the measurements one has to do tedious and time consuming preparations (setting up of special targets, calibrating of time-of-flight (TOF) equipment, proper adjustment of the recording apparatus, etc.).
- After most of the measurements one has to extract the relevant beam property parameters by lengthy calculations (particle density in phase space, radial and axial oscillation amplitudes, absolute energy from TOF etc.).

Obviously the above tasks can be taken over by an on-line computer. We see the main benefits of such a computer controlled beam diagnostics in the following facts:

+Present address: Gesellschaft für Schwerionenforschung, Darmstadt

1. The whole measuring procedure is extremely fast compared to our old systems.
2. The results are gained in a standardized way independent of the special operator.
3. Beam diagnostics can be performed by personnel without special training.

The first argument is the most important one. This property will allow us in the future to extend the system to computer-aided adjustment of beam parameters. A continuous control of the cyclotron, however, with no operator guidance seems unrealistic at present. Fortunately our cyclotron once adjusted has proved to be very stable.

## 2. Computer Configuration

### 2.1 Hardware

The computer system (fig. 1) is a NOVA 2/10 with 32 k of memory, two disks, two terminals and a CAMAC branch controller. A 200 m long CAMAC branch (fig.2) connects the 5 crates in the control room, the experimental area and the cyclotron vault. Though two of the crates are installed in a high level $\gamma$ and neutron field, we have not yet observed any damage due to radiation. The terminals consist of a 'Silent'-console (keybord, printer and 2 casette tapes) and a home-made TV-display with alphanumeric and graphic facilities. The screen resolution is 256×256 points for graphic and 32×36 characters for alphanumeric output. The two consoles are driven independently sharing one display control. The cost for the whole system was approximately 100 000 DM.

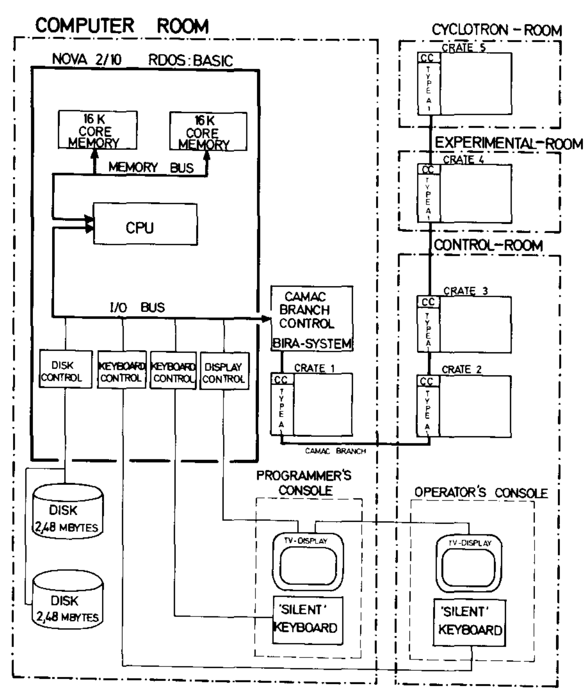


Fig. 1: Control system configuration

Proc. 7th Int. Conf. on Cyclotrons and their Applications (Birkhäuser, Basel, 1975), p. 538-541

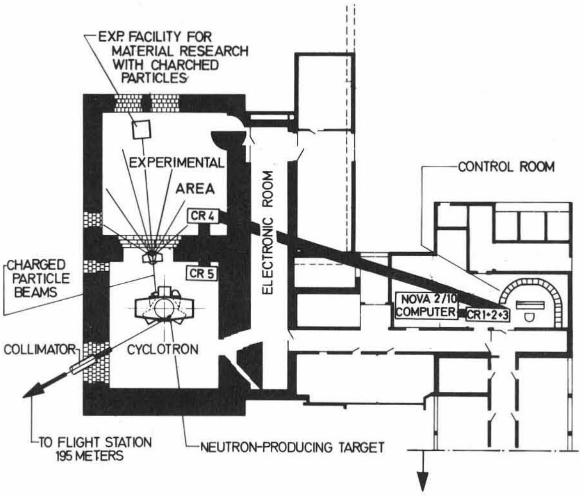


Fig. 2: Position of the five CAMAC crates around the cyclotron. The connecting parallel branch-highway is 200 m long

## 2.2 Software

As a common language for all measuring programs we use BASIC running under the real time disk operating system, RDOS. The reasons for the choice of BASIC can be summarized in its interactivity and the way to 'write-and-test' programs. The present version is a fast multiuser-swapping extended BASIC,with highlights like: fast matrix manipulation statements, program-swapping via the chain-mechanism and library maintenance facilities. For CAMAC I/O we have defined statements for declaring modules and performing single word transfers. For cases where high speed data transfers are required we have implemented three modes of fast data input: the normal list mode, the spectrum mode (increment-one) and the multi-scaling mode (increment-n). Input and output via CAMAC and other peripherals are performed by short assembler subroutines and are available as standard BASIC Call statements[2]). The kernel for the control tasks, 'CICERO', is an interpreter written in BASIC. To give to the operators the whole interactivity of BASIC forced us to find simple commands for complex actions. So the 'language' by which the operator can communicate with the computer is a very simple command oriented language, with only one 'key'-character as a command. The main commands are the 'RETURN'- and the 'ESCAPE'-key for starting and interrupting programs. Some other keys like 'H'-showing the list of the actually possible commands - and 'Z' - to leave a program - are common to all programs. In some special cases the communication with the program is made via a question/answer play.

# 3. Measuring Programs

CICERO once initiated displays a set of diagnostic programs (fig. 3) on the TV-screen in the control room. From this menu the cyclotron operator decides upon the requested diagnostic procedure by simply writing the appropriate number on his alphanumeric keybord. After a short question/answer play the computer autonomously executes the diagnostic task and displays the results on the TV-screen. In the following subsections the subprograms are described in more detail.

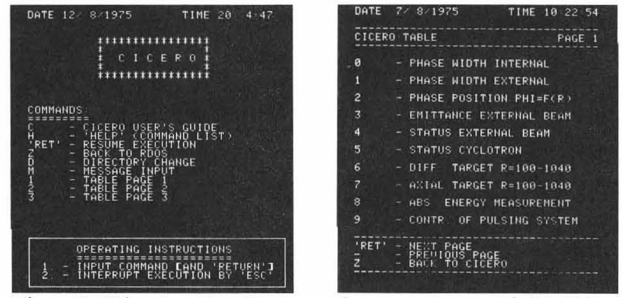


Fig. 3: First set of measuring programs right displayed by CICERO on the TV-screen in the control room together with a list of the possible commands (left)

## 3.1 Status Programs

A large number of cyclotron parameters are now measured via a CAMAC controlled integrating digital voltmeter (Solatron LM 1604, 5 digits) and 8×15 relais multiplexers (Borer 1701). The frequencies from 3 NMR-probes are counted via CAMAC scalers and timers (SEN 2024+2014). The display pictures in fig. 4 shows the parameters recorded at present. An especially useful mode is the 'drift test'. It provides a continuous surveillance of all power supplies and warns the operator if any component requires special attention. A library of operating parameters for each user is kept on the storage disk. At present the hardware for monitoring the settings in the axial injection system and trimcoils is installed.


Fig. 4: Computer display of commands for (left) and results of (right) parameter measurement. An asterisk behind the nominal value indicates a difference between actual and nominal

3.2 Emittance Measuring System

The new fast emittance measuring system, built into the beam line directly behind extraction consists of a x-y-slit actuated by stepper motors (300 Hz, 1 mm=10 steps) controlled via a standard CAMAC programmed pulse generator (SEN 2016) and a fast linear beam scanner (fig. 5). The rotary motion of this scanner is transformed into a linear one by a cardioid-shaped path. Up to 1000 revolutions per minute could be reached. The position and sampling signals are generated by an incremental magnetic shaft encoder (200 counts/360$^{\circ}$). In addition, the following CAMAC moduls are used: dual position encoder (SEN 2109), 8 bit ADC for sampling of amplified beam current (NE 7028), digital output (NE7054) for several control functions and a digital input (NE 7054) for status information. With this unit it is now possible to measure and display the horizontal or vertical emittance of the extracted beam within 30 sec. Fig. 6 shows an isometric display of the raw data taken with this unit. Up to now the adjustment of the standard values for the beam guiding system and the beam current are not computer controlled. The whole procedure and a representative result of such an emittance measurement is displayed in fig. 7.

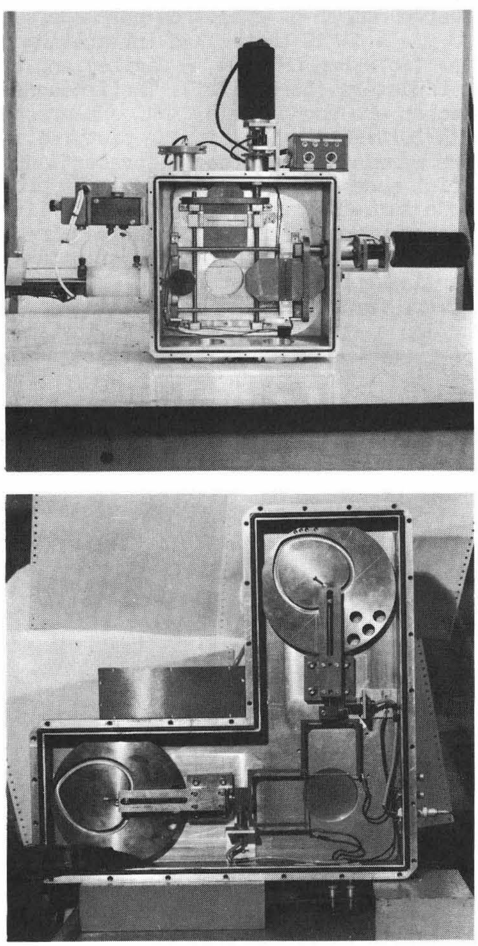

Fig. 5: Slit system actuated by stepper motors (top) and a fast linear beam scanner (bottom) for measuring the emittance of the extracted beam

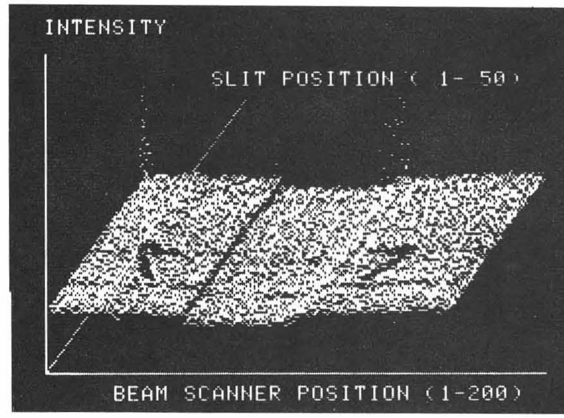


Fig. 6: Display of raw data of an emittance measurement taken with 1 µA beam current. The beam is scanned twice per revolution, therefore two peaks occur on the display

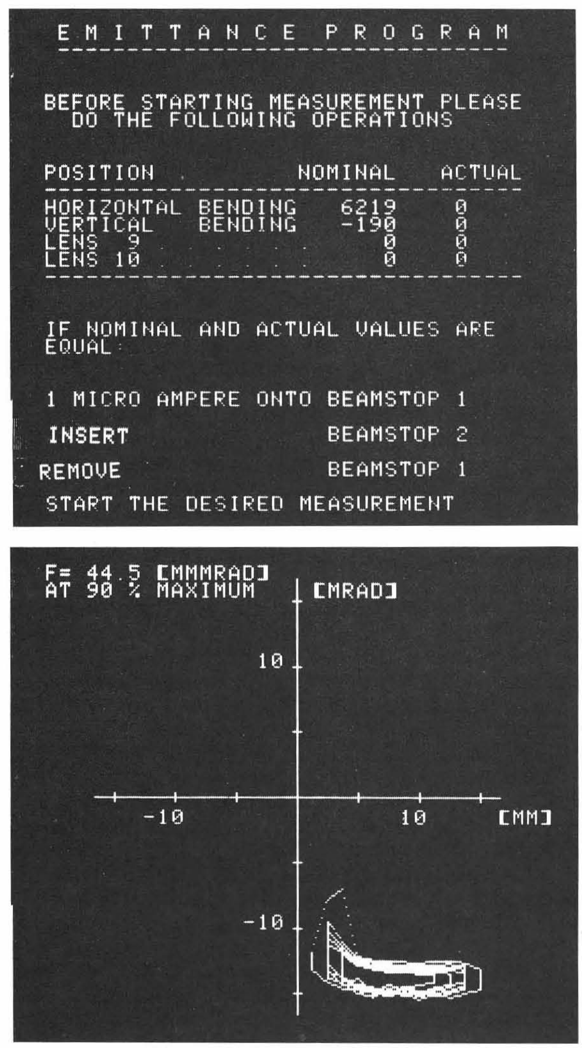


Fig. 7: Top: List of instructions for operator before starting the emittance measurement. Bottom: emittance area on computer display; the curve is drawn at 10 % of maximum intensity

### 3.3 Phase Measurements

The basic hardware for the following measurements

- phase width of internal and external beam via TOF (prompt $\gamma$'s)
- phase as a function of radius via TOF (prompt $\gamma$'s)
- absolute energy measurement via TOF (prompt $\gamma$'s)
- quality control of pulsing systems via TOF (scattering particles and prompt $\gamma$'s)

has been described previously[1,3]. To computerize these measurements only a standard 11 bit CAMAC ADC (NE 9060) and a home-made 4x3 bit 50 Ω-multiplexer for the fast signals were required. A measurement of the internal phase width takes about 10 sec. An example is shown in fig. 8.

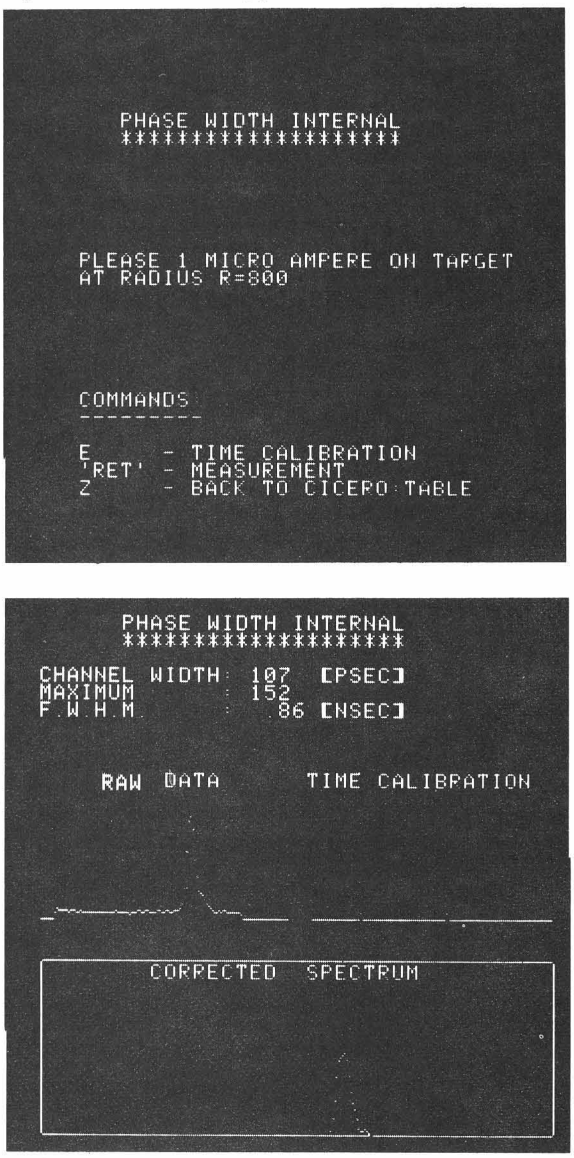


Fig. 8: Computer display for the measurement of the phase width of the internal beam. Top: before measurement; bottom: display of results

### 3.4 Radial and Axial Oscillations

As soon as the new CAMAC controlled target input machine is in action we will add the measurement of the radial-oscillations as published earlier[4]. To study axial oscillations a special target (fig. 9) consisting of a small rotating disk with a tantal wire on it driven by a water turbine has been developed.

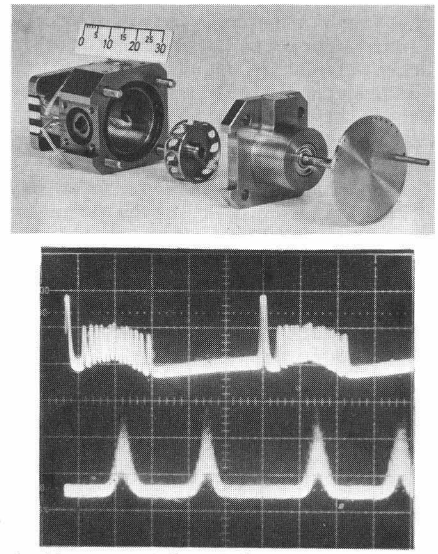

Fig. 9: Water turbine driven beam scanner for the measurement of the axial internal beam distribution. Oscilloscope picture: axial position signals at 1 mm intervals (upper trace) and axial intensity distribution at R = 500 for 1.5 μA beam current (lower trace).

### Acknowledgements

We wish to thank all those who helped in this work, particularly F. Schulz and his cyclotron crew, K. Heidenreich for building up the electronics, G. Bauer, H. Bellemann and R. Schütz for design and installation of the mechanical equipments and B.Volk for this work on CICERO.

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