

THE OPERATION OF THE GANIL CONTROL SYSTEM

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ABSTRACT

When the first GANIL beams were obtained the control system was operating in an elementary way ; the system behaved almost like a huge multiplexer. Now a large number of programs have been written ; they allow to take benefit of the full power of the computers ; they help the operators for starting, tuning and monitoring the accelerator. The paper gives a general description of these programs which are executed on the central computer : it shows how the accelerator is controlled either directly or via dedicated microprocessors. Informations are also given on the alarm system.

ted to a microprocessor is first transmitted to the MITRA 125, which will know from its data base what to do to perform the requested operation.

Special attention must be paid to the following point : if the operator has only requested to read an information immediately available to the microprocessor, he will get the answer quickly ; if he has requested to perform a complicated process, the final answer may come after several minutes ; it is strongly advised that the microprocessor be programmed so as to send from time to time "soothing" messages to let the operator know that the process is under way.

1. GENERAL INFORMATIONS ON THE CONTROL SYSTEMS

The GANIL control system has been described elsewhere^{1,2,3,4}. However it seems useful to summarize its main features, that have to be known to use it properly.

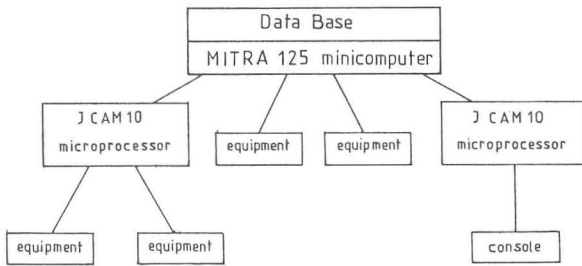


Fig. 1 : Logical structure of the control system.

The logical structure of the control system is shown on figure 1. Two kinds of processors appear on that figure : one minicomputer and several microprocessors (which include an Intel 8080 chip). Actually there are 15 microprocessors : 6 of them control the console, while the 9 others are devoted to special subsystems like RF cavities, phasing mechanisms and beam data collection. These microprocessors perform local tasks which would take too much time of the MITRA 125 if they were treated by this minicomputer.

What is referred to as equipment on figure 1 is essentially an elementary device : a power supply, a motor, a current on a target and so on. At the present time about 1500 equipments are directly connected to the minicomputer : each of which is the object of a special entry in the data base ; each of these equipments is known from the operator by its "operational name", a string of 16 characters chosen so as to be self explaining. The physical connections between the minicomputer, the microprocessors and the equipments involve serial Camac loops ; hence they differ deeply from what is shown in figure 1 ; however from the operator point of view figure 1 stresses an important point : the control system is a centralized one ; every information through it involves the minicomputer ; there is no direct link between microprocessors. For instance an operator request for controlling an equipment connect-



Fig. 2 : The main console.

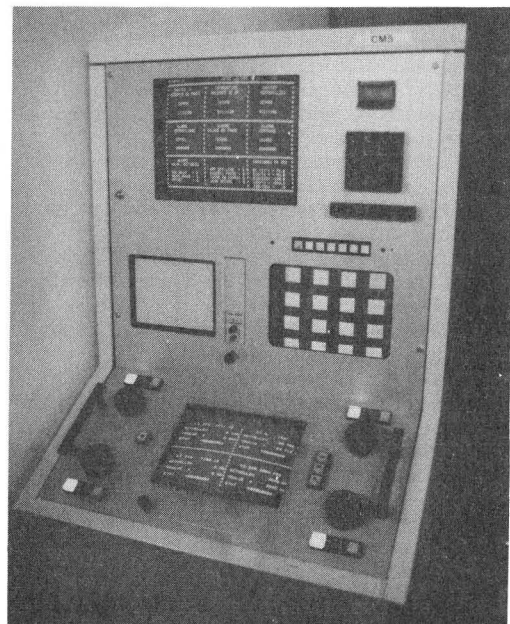


Fig. 3 : A movable console.

The main console is shown on figure 2, while figure 3 shows a movable console, a subset of the main console. It must be pointed out that there is no alphanumeric keyboard on the consoles, only small numeric ones to enter digital values. The operator has never to deal with syntactic problems ; neither has he to memorize operational names ; taking benefit of a large number of touch panels, the console proposes sets of names between which the operator chooses with a single finger. It must be understood that an operator request generally implies that the operator touch sequentially several knobs or pseudo-knobs ; all the sequence is controlled by the console microprocessor, which sends a message to the minicomputer only when the sequence is finished, and only if it is considered as being coherent.

The consoles offer several facilities. Of course one can control the equipments individually, on the basis of one knob on the console controlling one equipment. It was the way the accelerator was tuned during the first few weeks of its operation. This tedious procedure is now replaced by global operations involving tasks that can be executed on the minicomputer at the operator request. More than 100 tasks are now available ; they are considered as being only the first layer of the software needed to operate the accelerator quickly and comfortably. We are going to give more informations on 3 classes of tasks : starting, tuning and surveying tasks. Then we will explain what are the other facilities available on the console : the signal observation system, the synopses, the alarm screen.

2. INITIAL SETTING

An off-line Fortran code named PARAM computes the various parameters necessary to start the machine and the main beam characteristics, stores the results on MITRA disk-file for use by on-line tasks.

Each equipment can be controlled one by one with a shaft encoder. But because of their large number of them and the complexity of some dedicated subsystems, specific tasks have been written to set quickly the various parameters with a high degree of reproductibility.

- The power supplies (about 220 regulated current power supplies, those of the experimental areas not included) are automatically switched on and set to the nominal values, previously logged on the computer disk-file, with different user tasks :LIGNE for the beam-line quadrupoles and steerers, ALC1C2 for the SSC's trim coils, ALIE for the injection and ejection elements, NAPOL for the injector trim coils. Interactive facilities allow a section by section control and relevant messages appear on the TV screen for operation guidance. For the beam-line deviation magnets, the auxiliary coils are first set to the nominal value and then a cycling procedure is performed on the main coil by the specific task CYCDIP.

The main magnetic field of the SSC's is first cycled under the control of a dedicated microprocessor, the other power-supplies (trim coils, injection and ejection elements) are set up only when the final main coil current is reached.

- The two SSC magnets are balanced with the routine EQUSEC which moves 4 Hall probes through the yoke, measures the field level at the reference radius of 2.330 m on the four sector axis, computes and sets the current in each auxiliary coil to balance or to reach the field level introduced as an input for each sector, with an accuracy of ± 1 gauss. The Hall gaussmeters are on-line controlled and use a 6809 microprocessor to interpolate in a calibration table : an adequate field value is then directly sent to the main computer.

- The six RF systems⁵ are controlled by four local microprocessors (one per cyclotron and one for the

buncher) which keep the main computer informed of their operation. Specific codes named I1HF for the injector, R1HF for the buncher, C1HF for the two RF cavities of SSC1 and C2HF for the two cavities of SSC2 allow various actions : starting and stopping the HF, reading the status, adjusting the dee voltage.

The RF phase system is centralized for all resonators and is also controlled by a dedicated microprocessor. Phase adjustments on the different cavities are done with an user task : FASPOT.

3. AUTOMATIC BEAM OPTIMIZATION

The development of computer optimization procedures requires a perfect knowledge of the relation between machine parameters and beam properties and a highly dependable beam diagnostic system. From the starting of the GANIL accelerators some algorithms which correlate parameters to beam properties have been successfully tested and are now used for operation and for beam studies.

The main tuning procedures used for the SSC's such as beam alignment at injection, isochronization, beam centering, optimization of RF parameters and some others operating tasks such as : buncher phase adjustment, beam profiles control and display, beam emission limitation are briefly described.

3.1 Beam alignment at injection

By varying a steering magnet current the half beam intensity is measured successively on the right side and on the left side of the diagnostic sensor located at the SSC1 or SSC2 input. The best beam alignment is then obtained for the half-sum of these two current values. Using this method the task INCSS automatically aligns the beam at the input of each SSC.

3.2 Field correction

An interactive routine ISOGRO developed to optimize the isochronism or another phase law inside the SSC's has been previously described^{6,7}. Last improvements obtained are presented in another paper of this conference⁸. So the computer aid and the main console facilities used in this program are just recalled in this paper.

The 15 beam central phase measurements along a valley axis controlled by a microprocessor are displayed on the TV screen. Observing the shape of the curve and taking into account some simple criteria an interactive dialogue leads the operator to choose what parameter has to be optimized :

- a linear radial dependence of the central phase can be corrected by adjusting only the main magnetic field. The operator chooses the option "NIV" and two probes to delimit the radius range for the treatment. The code computes the slope of the best straight line fitting the measured points and gives in mA the needed change on the main coil current to have a flat curve as shown on figure 4.

- the trim-coil currents can be adjusted so that the law "phase versus radius" follows an theoretical curve given in the program. The operator points the cursor on the option "ISO", chooses the radius range and the degree of polynomial used to fit the experimental curve. In few minutes, the code computes the new trim coils currents according to the method described in⁷. A new measurement is proposed to check the effect on the new beam and to proceed in tuning the acceleration if necessary. This task has been running since the starting of SSC1 in June 82 and proves to be a

very helpful tool to refine in a fast and pleasant way the isochronism or any given phase law into the SSC's within an accuracy of ± 2 degrees.

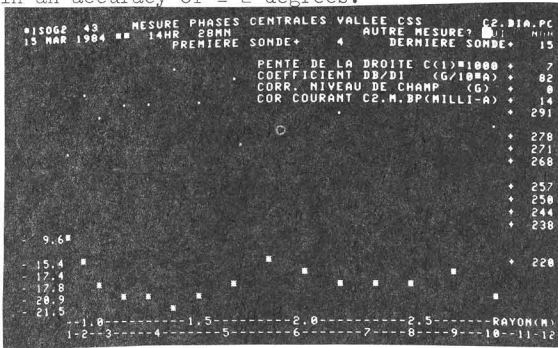


Fig. 4 Beam central phase versus radius measured in SSC2 and main coil current correction computed with ISOGRO code.

3.3 Beam centering

Magnetic field being established and then isochronized as described in § 2, 3.2 a slight unbalancing can remain which gives a beam off-centering. The interactive on-line task TROPIC moves successively the radial differential probes along the axis of the 4 sectors. The acquisitions of the beam current are treated and lead to the turn characteristics such as the center of gravity of the successive turns, their radial width, the turn separation. The results obtained for each probe are stored on the MITRA disk-file and are displayed on the TV screen. Then another task named CENTRE uses all these data to compute the corresponding corrections on the auxiliary and "nose" coils according to the method described in⁹. Fig. 5 presents the results obtained with the oxygen beam accelerated at the energy of 95 MeV/A. For this example the beam off-centering in sectors D and B corresponds to an unbalancing $\Delta B/B$ of $\pm 5 \cdot 10^{-4}$. In this case no correction is needed either on sectors C and A or in the injection area with "nose" coils. The complete treatment which has to be performed for each new case of acceleration takes about 2 hours : generally only one iteration is needed.

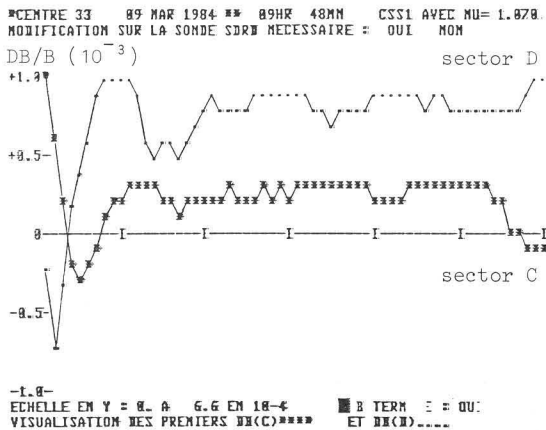


Fig. 5 : Magnetic field defects computed by the task CENTRE which can be corrected with auxiliary coil currents.

3.4 Optimization of the RF phase and extraction turn centering

Using the beam central phase measurements in the beam lines the RF phase of SSC1 or SSC2 is computed by the task PHAREG according to the method described in⁸ ; this precalculated value is accurate enough to inject

and accelerate the beam. Then another task named PICNEJ moves a probe just in front of the ejection electrostatic deflector, measures the current with a step of one mm and displays the peaks on the TV screen as shown on Fig. 6. By observing the shape and the position of the peaks the operator can select what parameter has to be changed, the RF phase or the RF voltage, to obtain the best turn separation or to center the last turn just on the deflector axis.

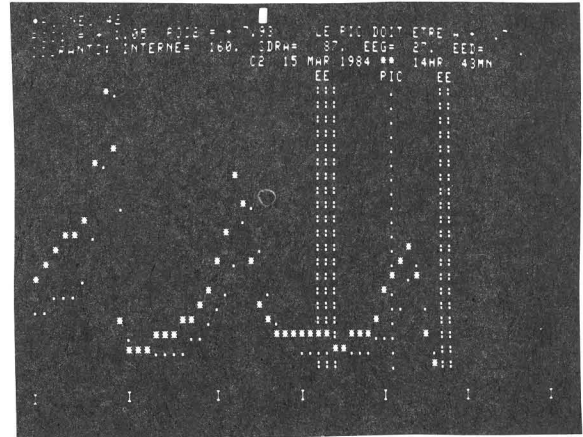


Fig. 6 : Last turns in SSC2 displayed with PICNEJ code for two values (points and stars) of the RF dee voltage.

3.5 Buncher RF phase adjustment

According to the method described in⁸ the code CALGR1 performs all the measurements necessary to adjust the buncher phase.

3.6 Beam profile grids and beam slits monitoring

- The task COPROF controls section by section the large number of profile grids (about 100) placed along the beam-lines between the 3 cyclotrons and on the experimental areas. To the operator request, the beam-line is drawn on a TV screen together with the profile grid positions.

- For each grid the dedicated microprocessor performs the current acquisitions on the grid wires and computes the profile area, the beam center, the width in the horizontal and vertical planes. The numerical values are sent to the central computer where different codes display these results : for example the code GRAFAI displays the beam centers compared to the optical axis and the vertical and horizontal beam envelopes.

- Six pairs of slits are located in 3 points of the beam-lines to limit the vertical and horizontal beam emittances. The code LIMEMI moves these dedicated slits to achieve the beam emittance values given as an input by the operator. This task is also very useful to adjust properly the beam intensity on the physicist target.

4. SURVEYING TASKS

As an addition to the alarm system (§ 7) some user tasks have been written to find quickly where and on what equipment something is running wrong.

- For each SSC the task CINEJ displays on the TV screen the beam losses measured, every 300 ms, on the injection and ejection diagnostic sensors. This code is also useful to optimize the injection and ejection parameters.

- For the RF phases a warning alarm is sent on the dedicated screen and the code ETAFAS, executed at the operator request, gives the complete status of the 6 RF cavities and the nominal values.

- For the RF dee voltage and the power supply values

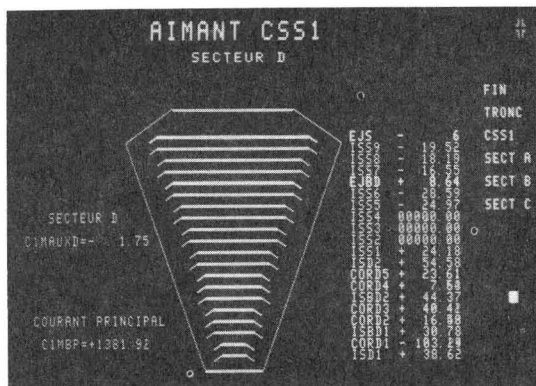
a task named OBSERV reads all these parameters and compares their values to the nominal ones previously saved on the computer disk-file by another code : STOPAR. The list of the abnormal parameters is written on the TV screen.

5. THE SIGNAL OBSERVATION SYSTEM

About 300 analog signals can be displayed on oscilloscopes in the control room. Most of them come from the beam profile monitors¹⁰. They provide a very convenient mean of controlling visually the beam size and position. The signals are transmitted from the monitors via the so called "Signal Observation System", a subset of the system designed at CERN for the PS¹¹. Here again touch panels are used to assign any of the signals to any of the scopes. It must be mentioned that the signals from the profile monitors are also digitized by microprocessors, and can be accessed by programs executed on the minicomputer.

6. SYNOPSES

Even if they are not essential for the accelerator operation, they provide the confort that helps the operator's every day life. Displayed on color TV screens, they consist of a fixed background, plus refreshed parts, that can be either numerical values or graphic symbols. Of course red is used to draw the operator's attention on elements being in an abnormal situation. As an example, figure 7 shows the trim coils in one sector of the SSC1. Their currents are displayed on the right part of the figure, while the color of the trim coils reminds the operator which ones are in series with the other sectors, and which ones are not.



7. THE ALARM SYSTEM

The general philosophy of the control system is that it is idle if not asked from the consoles to do something. Equipments, process microprocessors, are basically slaves that only answer or obey to the minicomputer.

One big exception to that rule is the alarm system, by which an equipment, a process microprocessor, on its own initiative can send a short message to the minicomputer.

From the hardware point of view, alarms are Camac Look-At-Me. The adress of the LAM source is used to find in the data base the text of a message to be displayed on the alarm screen, on the basis of one line edited for each alarm.

Some of them are simple warnings, others require immediate attention from the operator (a tripped power supply results in a lost of the beam). Color code helps to distinguish between alarms.

8. CONCLUSION

One can say that the first year of operation has been a year of completion for the control system ; the number of equipments known by the data base has doubled; it is still growing as the experimental areas are progressively equipped.

The hardware (mainly Camac) and the basic software can be considered as stabilized. (Basic software refers to the system software that has been written to take care of the Camac, the consoles, the process microprocessors).

Still rapidly growing is the application software : the tasks needed to help the operator. As this software is being developped, some limitations of the control system appear.

First the MITRA 125 is now felt as being too slow and provisions have been made to replace it by a faster computer. In the same time, the disks will be replaced by much larger ones.

Second, some of the JCAM 10 microprocessors are considered as bottle necks, from two points of view. First, a general consideration is that they are very slow to program, since they have been programmed in assembler. Second, some of them (mainly the console microprocessors) are not quick enough. That is the reason why we are now developping new microprocessors, built around a M68000 which will be programmed in LTR, the real time structured langage which is already used to program the minicomputer.

Third, as the application software becomes more and more sophisticated, needs have appeared for high resolution color graphic screens. Since such peripherals were not available when the system software has been devised, additional software will be written to handle them.

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