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DATA ACQUISITION WITH THE BOL NUCLEAR DETECTION SYSTEM

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The acquisition of nuclear reaction data using the BOL-detection system involves three interacting computers. Data are either stored on magnetic tape for off-line analysis or directly processed on-line depending on various circumstances. Procedures for experiment-control and -checking are briefly described.

1. Introduction

Recording and evaluating nuclear reaction data with the BOL detection system[1–3]) involves an on-line coupled computer-triad of two PDP8 data processors and an EL-X8 computer[4]). The acquisition includes adjustment of various instrumental parameters, error detection, macroscopic control of the detection system and the event-wise recording of measured data on magnetic tape. The computer configuration is programmed in a flexible manner, to allow the processors to run either independently or cooperatively, as needed (fig. 1). All three computers operate in time/memory-sharing mode and are, as far as capacity permits, always available for having additional programs run macroscopically in parallel. The operating system MONIKOR[5]), for the (4 k, 12 bits) PDP8 processor, is obviously considerably less sophisticated than the time-sharing system WAMMES[6]) for the (48 k, 27 bits) EL-X8 computer. Nevertheless it allows independent or semi-independent tree-structured modular programs to be executed in parallel. Characteristics of the MONIKOR system are given in an appendix.

As described elsewhere[3]) the electronic non-computer part of the BOL-system, operates almost autonomously: only high-level control functions are awarded to the computers. One of the PDP8's (P1) acts as direct supervisor, in a closed control-loop. Intricate control decisions are taken in close cooperation with the other computers and with the operator/physicist, all of them appropriately "programmed".

2. Initialization procedures

The system is made operational in the following sequence of steps (omitting minor details):

– evacuating the scattering chamber to 10^{-6} torr;
– cooling the innermost shell of the scattering chamber to $-20°$C;
– switching on the detector voltages at a low value, checking currents and noise of all detectors, slowly increasing the detector voltages to the operating value. (Sometimes a few detectors give too much noise and may then be used with reduced voltages.);
– electronic testing of the complete detection channels to be used;
– checking the data flow to the PDP8 originating from a ^{241}Am source, which is mounted on the target-ladder.

Before and during operation it is checked regularly as to whether:

– all complete detection channels are operating (visible on the console);
– no (permanent) bit errors (presence or absence) occur in any of the operating detection channels. To this purpose, various PDP8 test programs have been developed.

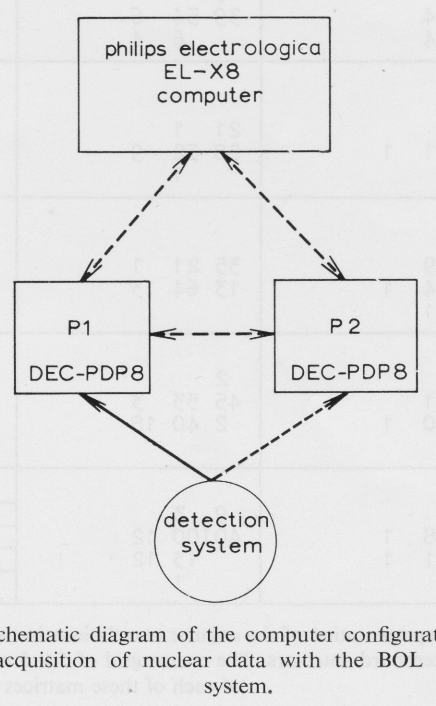

Fig. 1. Schematic diagram of the computer configuration used for the acquisition of nuclear data with the BOL detection system.

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Apart from delays due to repairs, 18 h are needed to reach the operational stage. Then the external beam from the IKO-synchrocyclotron is transported to a luminescent television-viewed target just before the scattering chamber. The beam optics[2]) is adjusted such that a small spot at optimal intensity with sharp contours is produced on the TV-target. Then a special 5 mm thick graphite target with a 1 mm hole is positioned at the centre of the scattering chamber. Behind the scattering chamber, a luminescent screen, viewed by a photomultiplier, is turned into the beam. With an extremely low beam current, to avoid radiation damage of the detectors, the beam is then allowed to enter the scattering chamber. The output signal of the photomultiplier is amplified and integrated to provide current monitoring at the low beam intensity. Using this current monitor the beam optics is further adjusted to produce maximum current through the hole. Applying this criterion the beam is focussed at the centre of the scattering chamber. When the optimum has been reached, slits near the cyclotron are critically adjusted such that the spotsize is of the same dimension as the 1 mm hole in the graphite target. A final scan through all adjustable parameters then delivers an optimal beam spot. With horizontal and vertical 0.5 mm wide gold strips, mounted in the target-ladder, the spot structure may be scanned using the count rate in the forward detectors as a measure. For normal use, though, a faster and more relevant method to check the beam conditions in the scattering chamber (size, shape, position, direction), which is based on the unique facilities of the Checkerboard detectors[7]) has been developed. The method[8]) is based on the observation of coplanar pairs of particles produced by elastic scattering on a CH_2 or CD_2 target positioned at the centre of the scattering chamber. Suitably chosen pairs of detection channels may detect the kinematical correlations (viz. fig. 2) from which the relevant beam parameters may be inferred. Since the computer capacity of the PDP8 processor is not sufficient for this task, this procedure is executed on-line with the EL-X8. A computer program, developed for this beam analysis, provides the experimenter with the beam-deviation and spread-parameters, according to which the appropriate beam transport elements may be re-adjusted. The accuracy of this beam adjustment is found to be of the order of the beam stability, i.e. 0.2 mm at the target. It should be stressed that with this technique the total angular resolution, including all directional dispersion effects, is determined in a single direct measurement. An example is given in fig. 3.

All equipment of the system (cyclotron, BOL detec-

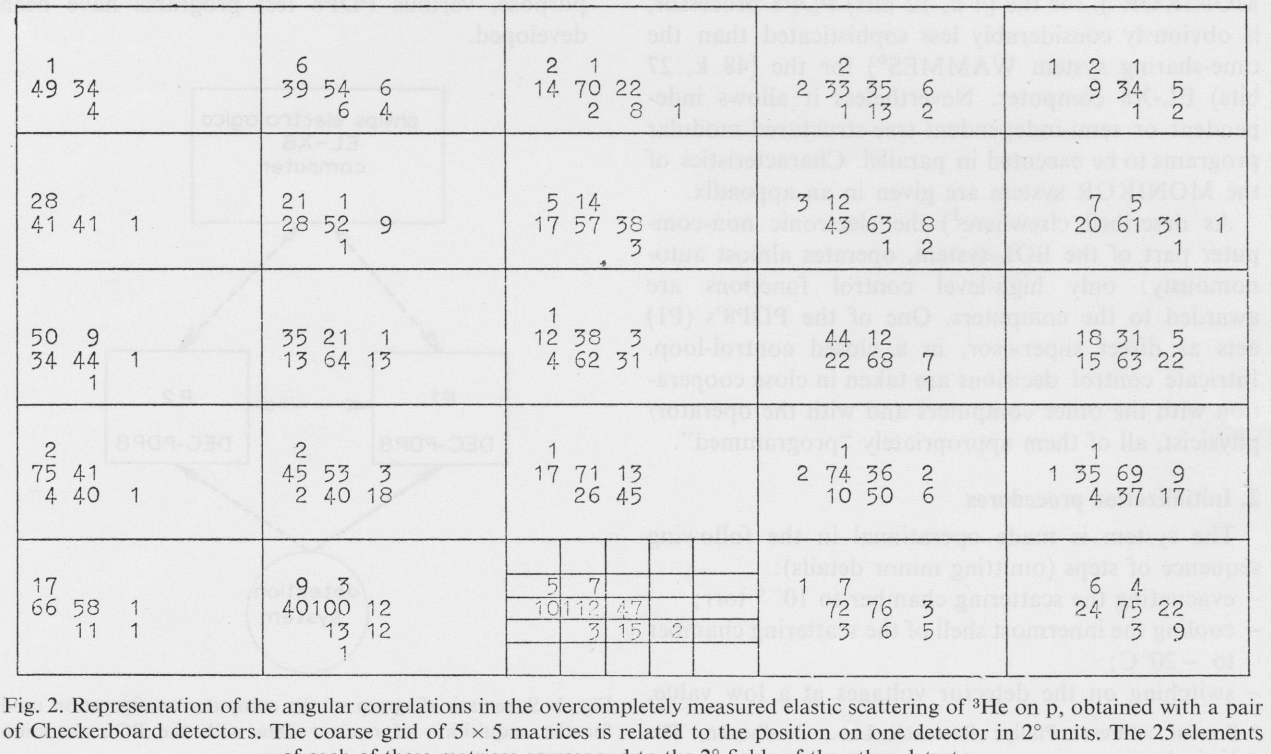

Fig. 2. Representation of the angular correlations in the overcompletely measured elastic scattering of ^3He on p, obtained with a pair of Checkerboard detectors. The coarse grid of 5 × 5 matrices is related to the position on one detector in 2° units. The 25 elements of each of these matrices correspond to the 2° fields of the other detector.

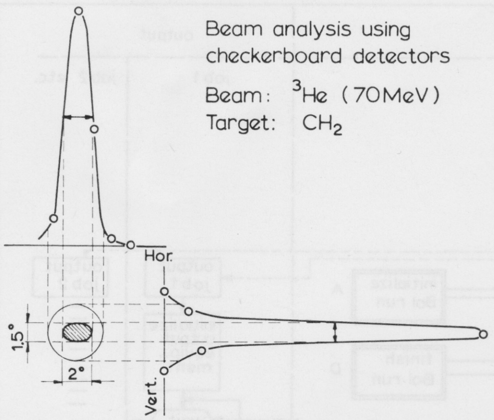

Fig. 3. The convolution of all angular dispersions in horizontal and in vertical direction as deduced by a computer program from the angular correlation, shown in fig. 2.

tion system and complete computer configuration) being available, various aspects of the quality of the data from all detection channels can now be checked, e.g. *E–ΔE* correlations, location codes and energy-spectra. A general test program provides information regarding such aspects. Minor errors, possibly showing up in some detection channels are accepted at this stage and corrected for in the later off-line analysis, rather than spending time on reparations.

When finally sufficient confidence has been acquired regarding the reliability of the system, the actual experiment is started. The time required to reach this second stage of the starting-up procedure is generally a few hours.

3. Data-recording

Data are recorded normally with one of the two magnetic tape units of the PDP8 (P1). The recording schedule depends to some extent on the specific experiment. The experimental runs are regularly alternated with checkruns[6]). The high degree of autonomy of the electronics allows control of the detection system by P1 through simple hardware. The main hardware instructions are listed in table 1.

In fig. 4 a flow diagram is given of the data input program BOLIN. This program fits into a simplified version of the WINDOW programming system[6]) as realized within the frame of the PDP8 MONIKOR system (viz. appendix). BOLIN is in fact a program-module (job) that controls the experimental data flow from the BOL detection system to P1. The 72 bits event-records are read from the interface-buffer and stored in standard blocks [WINDOW-format[6])] in core memory. The job program BOLIN can be combined with various output-jobs, available for all output channels of P1. Thus, the data flow from the BOL-system can be transferred to the EL-X8, the other PDP8 (P2), the magnetic tape units or the teletype in any desired combination. The full I/O switching process is programmed in a protocol-job (viz. appendix) by specifying the program-modules to be combined, the number of core-buffers to be used and the labels of the program parts where the input data may be inspected, selected and/or changed before they are transferred to the output job. In table 2 an example is given of the most simple protocol-job, defining a complete experimental run where all data are simultaneously transferred to the EL-X8 and written on magnetic tape. The use of program modules not only provides a basis for specifying rather complicated I/O processes so easily, but also, allows a modification of one program module without in general, requiring any change in other modules.

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TABLE 1
Hardware instructions for control of the detection system through P1.

– ON/OFF	:	CURRENT INTEGRATOR
– ON/OFF	:	CENTRAL UNIT
– ON/OFF	:	COINCIDENCE REQUIREMENT
– INVERT	:	CHECKERBOARD OFFSET ("PIANO") VOLTAGE
– SKIP	:	IF EVENT READY IN BUFFER (72 bits)
– READ	:	EVENTBUFFER (6 COMMANDS FOR 12 BIT WORDS)
– CLEAR	:	EVENTBUFFER
– REQUEST	:	CENTRAL SCALERS
– SKIP	:	IF CENTRAL SCALERS READY IN BUFFER (72 bits)
– READ	:	CENTRAL SCALERS BUFFER (6 COMMANDS FOR 12 BIT WORDS)
– CLEAR	:	CENTRAL SCALERS BUFFER

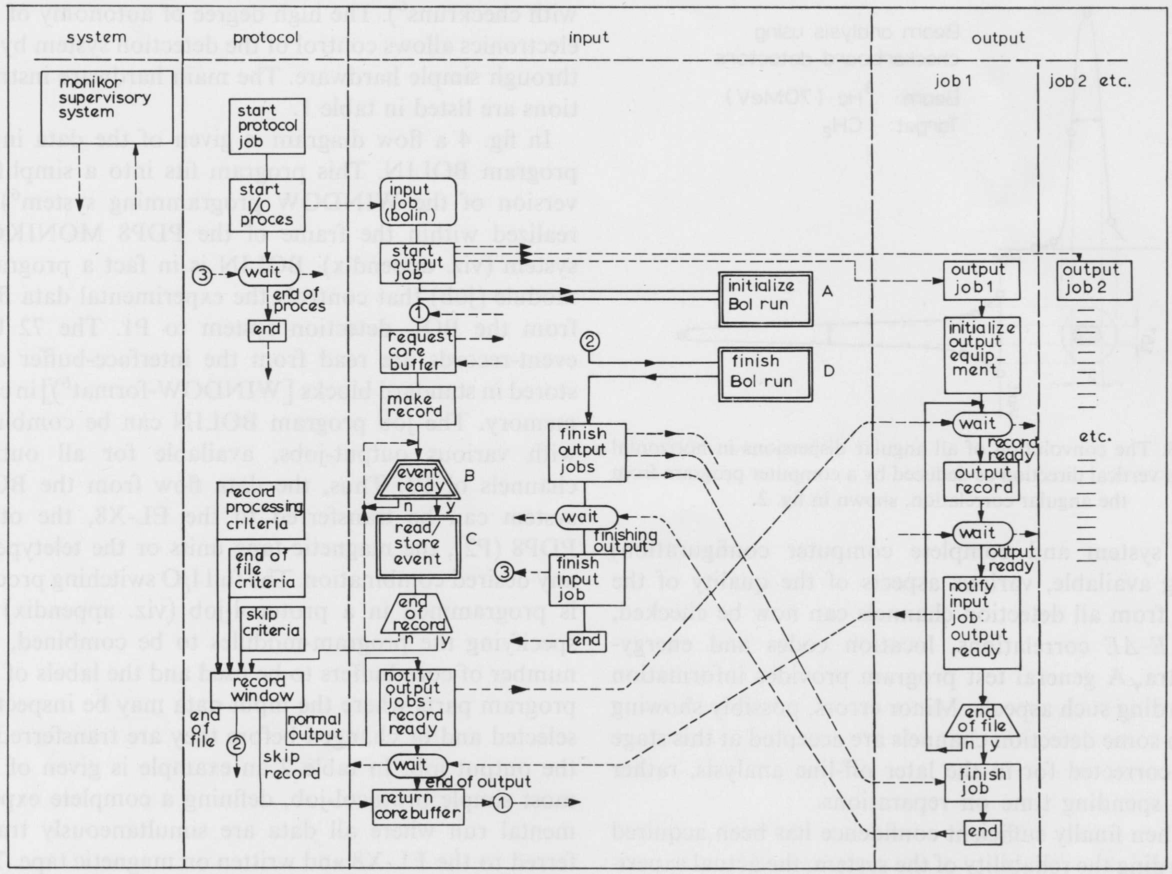

Fig. 4. Simplified flow diagram of the data acquisition program. The dashed lines indicate that control goes through the supervisory system. Besides the hierarchic structure the communication and synchronization between different software levels is indicated. Apart from the specific parts A, B, C, D, the presented logical functions belong to a standard I/O software system for the PDP8 (WINDOP).

TABLE 2

Example of a most simple protocol-job (program module) starting a tree structured I/O process that reads input data from the BOL detection system and switches them to a tape unit and to the on-line EL-X8 computer (by removing the name ELXOUT the data are written on magnetic tape only).

```
             BEGIN
             ø          / JOB ADMIN ADDRESS
             ø          / JOB ADMIN ADDRESS
             START
             JOBIO      / LABEL I/O PROCESS SPECS
WP1,         WAIT       / SEMAPHORE: WAIT FOR END OF PROCESS
             END

JOBIO,       BOLIN      / NAME INPUT JOB
             WP1        / LABEL WAIT POINT
             4          / NUMBER OF CORE BUFFERS(PAGES)
             WINDOW     / LABEL WINDOW ROUTINES
             ADMIN      / LABEL I/O ADMINISTRATION
             TAPOUT     / OUTPUT JOB(TAPE UNIT)
             ELXOUT     / OUTPUT JOB(EL-X8)
             ø          / END OF OUTPUT JOB LIST
```

They would like also to stipulate that the enthousiastic cooperation of the operating team made it actually possible to have these procedures used routinely.

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Appendix

MONIKOR, A MULTI-JOB PROCESSING SYSTEM FOR THE PDP8

The MONIKOR supervisory-system allows several independent or semi-independent job-programs to run macroscopically simultaneously. The system has been developed as a consequence of a number of requirements dictated by the application of a PDP8 as a coordinating element among several relatively autonomous "peripherals" including the experimental setup, two tape units, a disk, a display unit, other computers and a physicist! MONIKOR itself, however, is configuration independent. It requires only a teletype. The characteristics of the system include:

- possibility of programming on a high level;
- modular programs (jobs), usually with minimal restrictions on size or on hierarchic level;
- increased flexibility in combination of jobs and their mutual activation;
- running jobs asynchronously on a macroscopic level;
- switching times between jobs in the 10 μs range;
- time distribution between "active" job-programs only;
- use of memory space allotted to inactive jobs;
- reading in of jobs from disk, magnetic tape or paper-tape, as needed;
- loaders (themselves jobs) that run simultaneously with the other programs;
- continuous access to the active processes by the operator;
- standard functions (those within the system too) available for all jobs;
- waiting times minimized by using queuing-mechanisms;
- a free space of 20 pages (of 128 memory words) for simultaneously active jobs and data buffers (the system occupies 12 pages).

The MONIKOR system is built as follows: it consists of a set of bookkeeping subroutines, a central administration and some standard jobs (e.g. program loaders, teletype communication). The operator has almost continuously access to the system by using a command-job, which enables him to attach new high level jobs (so called protocols) to the running process and to examine and to modify internal conditions or address contents. A protocol-job, once started, automatically triggers a tree-structured process. Program-jobs synchronized at critical points are the building blocks of the process. During the process, jobs not yet attached are either read in from disk, magnetic tape or requested automatically via the teletype.

Job-programming for the MONIKOR system requires some additional rules, because the mutual synchronization of different jobs and peripherals is realized by using private "semaphores" in the jobs themselves. These semaphores are inserted at "critical points", where the program waits for the change of some internal or external condition.

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