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A Versatile Data Acquisition System and The ISOL Facility TRISTAN*

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Abstract

The on-line mass separator, TRISTAN, is located at Brookhaven's High Flux Beam Reactor. A Nielsen-type ion source, which can contain up to 8g. of ^{235}U in an external beam with a flux of $\sim 2 \times 10^9 \text{ n/cm}^2/\text{sec}$ is used to generate short-lived fission products. Experiments have been constructed on two of the five available beam lines to measure β - γ and γ - γ coincidences, γ - γ angular correlations and delayed neutron emissions. A Users Group has been formed to coordinate research between University groups and BNL. Developments planned for TRISTAN include FEBIAD, surface ionization and negative-surface ionization-type ion sources, and a He-jet system as well as construction of new experimental facilities. An off-line separator, ISTU, is available for the development program. We have constructed a versatile, modular data acquisition system to service experiments on TRISTAN and other nuclear research facilities at the HFBR using Camac interfacing. Standard, commercially-available electronic instruments and computer programs, such as FORTRAN and system routines, are used throughout. Simple interfaces have been built to adapt non-Camac equipment to Camac input registers. Up to eight different experiments can be multiplexed on the branch highway by a fast microprogrammed branch driver with a 4096 word memory. The branch driver delivers pre-processed data to a bus which links devices such as a central processor, 1 megaword core memory, tape drives, discs, display processor and terminal. The following features are offered: two 8192 channel pulse height analyzers, a 3-parameter coincidence unit, 4 multiscalers, a timed sequence of delayed γ -ray spectra (33 spectra of 4096 channels each), a 2-parameter (pulse height versus time-of-flight) analyzer, 16 scalers and 24 experimental interlocks. Up to 100 different spectra are available to users for display during an experiment. Event mode recording on magnetic tape and direct sorting into the 1 megaword array are used as appropriate. A master program, almost entirely written in FORTRAN, allows users to control and monitor each experiment with simple mnemonic codes. Analysis of the data is carried out on a companion computer devoted to data processing, allowing rapid sorting, plotting, listing and analysis of data.

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The Mass Separator

The ISOL facility TRISTAN is now operating at Brookhaven National Laboratory's High Flux Beam Reactor. The separator, shown schematically in Figure 1, uses a Nielsen-type ion source containing up to 8g. of ^{235}U , impregnated into a graphite matrix on the anode. The total power input to the ion source is typically about 850 W, yielding a target temperature on the order of 1500°C and a lifetime of about 200 hours. The ion source is in an external neutron beam with a flux of about $2 \times 10^9 \text{ n/cm}^2/\text{sec}$.

An einzel lens, electrostatic quadrupole singlet lens and a compression lens are available for focussing the ion beam before it enters the 90° sector magnet. The beam is brought to a horizontal focus in the collector box and another electrostatic quadrupole singlet lens, located before the switching magnet, is necessary to provide a horizontal focus on the moving tape collector. The vertical height of the beam is controlled by the compression lens.

The switching magnet allows the construction of up to five independent experiment stations. The desired facility is selected by varying the magnetic field and polarity. Three of the beam lines are presently being used. At a 45° port a moving tape collector has been set up to facilitate β and γ spectroscopy experiments which includes β - γ , γ - γ coincidences and γ - γ angular correlations. A $22\text{-}1/2^{\circ}$ port has a deposit box for removal of long-lived activities for chemical separations or isotope production. At the 0° port a tape collector has been installed for use in various types of delayed neutron studies including P_n measurements, ^3He neutron spectroscopy and time-of-flight spectroscopy.

Some results from the initial surveys made with TRISTAN are shown in Table I. While examining this table it should be noted that misalignment of the moving tape collector allowed only about 30% of the ion beam to strike the

tape (this problem has since been corrected) and that the data was taken at a flux of only 2×10^9 n/cm²/sec. When a beam collimator is removed, the flux will increase to about 10^{11} n/cm²/sec.

In the planning for this facility, it was recognized that a versatile and powerful data acquisition and analysis system would be necessary to support the wide range of experiments to be done at TRISTAN. At the same time it was necessary to upgrade the data collection at the nuclear physics experiments at the HFBR, which were supported primarily by an obsolete SDS 910, purchased in 1962. It was thought that a single system was possible to fulfill these functions.

Based on the experience gleaned from time-shared operation of the SDS 910, a number of goals were set up for the proposed system. These goals were as follows:

- 1) The use of commercial modules and commercially available interfaces wherever possible. Previous experience has shown that the laboratory engineering of specialized interface electronics is prohibitively expensive and leads also to a system which is not easily modified later in time.

- 2) The use of commercially available software wherever possible. This requirement dictates the use of the commercial computer's monitor and standard programs. As above, the use of specialized, locally developed software proves to be very expensive.

- 3) The writing of most of the code in a higher level language familiar to all scientists. This requirement dictates the use of FORTRAN.

- 4) The active participation of physicists in the planning and writing of the necessary codes. The avoidance of programming specialists saves considerable time and money, and tends to produce a system which is the most useful to the working scientists.

5) The use of a limited set of user executable commands for the user to control display, and print out the results of his experiment. No general operation lying outside the execution of the data acquisition code, which embodies these commands, is permitted to the user.

6) The availability of a separate, adjacent computational facility where the user may manipulate his data, free of the above constraints. The analysis computer has no interaction with the data acquisition computer, thus avoiding computer crashes which can seriously inconvenience many users.

The two-computer concept has been implemented at TRISTAN along the guidelines set forth above. The link between the computers is limited to magnetic tape. Except for program development the information flow between these computers is unidirectional.

Data Acquisition

Requirement 1 is satisfied by the use of NIM modules whose outputs are directed to CAMAC, a universal interface system. In order to provide for an efficient use of the CAMAC dataway, the CAMAC operations are controlled by a microprogrammed branch driver, which had been previously developed for use at the Los Alamos Meson Physics Facility, and which is commercially available. The MBD is a fast microprocessor (70 ns cycle time) which is capable of multiplexing up to eight separate channels of CAMAC input information. Each channel is initiated by an interrupt which triggers separate section of code stored in a position of the MBD's 4096 word memory. The basic function of each program module is to collect the experimental parameters presented by that channel and perform some operation on the event descriptors read in. The simplest operation is the buffering and subsequent storing of event descriptors on magnetic tape. Another operation is the incrementation of a memory word and the concomitant accumulation of a spectrum. Some action, such as the

termination of an experiment due to the operation of an interlock, may result from an MBD operation. Some simple calculations may be performed in the MBD, such as address masking, addition of a base address, or rudimentary arithmetical operations. The MBD is, however, primarily a traffic controller to shunt the experimental data to their proper locations in the system. The MBD micro-processor code comprises the largest block of non-FORTRAN software in this system.

The central processor of the data acquisition system is a PDP-11 computer, which has been chosen because of its use of a bus structure which lends itself to the asynchronous nature of data collection. This computer uses a 16 bit word structure. Figure 2 shows a block diagram illustrating the components of the system and the relationship between the two data busses of the system - namely the CAMAC dataway and the unibus of the PDP-11 computer.

The peripherals attached to the unibus, in addition to the MBD are a display processor (GT-40^{*} with a 19 inch display screen), two magnetic tapes (9 track, 800 bits/inch), two 2.5 megabyte disks, a 1 megaword core memory, a paper tape punch/reader, a terminal, and a PDP 11/20 central processor and its 32K memory. Because of this bus structure, and because of the MBD capability, it is possible for the MBD to directly access a peripheral without passing through the central processor. Extensive use is made of this capability; for example spectra may be directly accumulated and stored in the 1 megaword memory without involvement of the central processor. Displays may be similarly generated by the GT-40 without involving the central processor. Thus the major part of the data processing flow in this system is carried on without intervention of the PDP 11/20.

* The GT-40 features scrolling and operates in parallel with the ordinary typewriter terminal. The latter may be inhibited to reduce the amount of paper produced, and all text directed to the screen.

With this distributed processing capability the PDP 11/20 is left only with control, monitoring, and I/O functions to perform. Teletype commands initiate and terminate data acquisition on the various channels, monitor the status of the experiments, set-up displays, perform simple calculations of peak energies and areas, and allow transfer of data to magnetic tape as is appropriate. For fast chopper multi-parameter data, sorting of the events into spectra for storage in the megaword memory is done. For the multi-detector γ - γ coincidence experiment event mode buffers are sorted into spectra for monitoring purposes as well as being transferred to magnetic tape for later detailed analysis.

The role of the 1 megaword memory is an important one because of its use as a temporary or long-term storage of spectra. Spectra are stored as 128, 4096, or 8192 channels, with each channel consisting of two 16 bit words. The present system allows the storage of 23 8192 channel pulse height spectra, 33 4096 pulse height spectra corresponding to various time cuts in a two-parameter time-of-flight analyzer, 33 4096 pulse height spectra for successive time channels of a multiscaler associated with radioactive decay measurements, and 4 128 channel multiscalers for beta or delayed neutron counts.

A description of the use of the 8 MBD channels for the various TRISTAN and neutron-nuclear physics experiments at the HFBR is given succinctly in Table II. Channel 0 has the lowest priority. A detailed description of the various analyzers available to the experimenter are 1) a pulse height analyzer (8192 channels), 2) a two-parameter, time-of-flight versus pulse height analyzer used for fast chopper experiments, 3) a n-parameter gamma-gamma-time coincidence/ angular correlator system, where n may range up to 8, 4) an 8192 channel pulse height analyzer used in conjunction with a 3-crystal pair spectrometer at the Tailored-Beam facility, 5) 4 multiscaler channels, 6) a multispectra analyzer

accommodating 33 4096 channel time correlated spectra, and 7) a block of scaler and interlock data.

1) Channel 0 - auxiliary pulse height analyzer. The address output lines of an digitally stabilized ADC (Tracor/Northern NS623) plus high order routing fits are passed through a level converter, to provide the necessary TTL levels, and fed to a CAMAC input register (ORTEC RI 224). (See figure 3.) The data received line of the input register accepts the ADC ready signal, generating an interrupt to the MBD, which executes the appropriate code. The code reads and clears the input register, calculates and accesses the appropriate memory location in the 1 megaword core memory (DATARAM) and increments it, performing a carry to the high order word of the channel pair, if necessary. The data received signal, which is generated when reading the input register, is sent back to clear the ADC for the next operation.

2) Channel 1 - gamma multiscale. The operation of this channel is identical to that of the pulse height analyzer of channel 0, except that one of 32 base addresses for data storage is selected. The base address is determined by the state of a real time clock (ORTEC RC014), which is started by the time sequencer of the TRISTAN moving tape collector. Thus 32 different pulse height spectra are generated, each corresponding to a different time region of a decay curve. The minimum time channel is 1/16 sec long. The analyzer also generates a spectrum which is time integrated over all channels. All 33 spectra, each consisting of 4096 channels, are stored in the megaword core memory for later read out.

3) Channel 2 - gamma-gamma coincidence analyzer. A block diagram for the interface for this channel is given in figure 4. The purpose of this interface is to accept pairs of events from up to 8 detectors and the time relationship between events. Timing signal (T0-T7) are derived from each

detector and presented to the interface. If the required multiplicity (1-4) is met within the resolving time (40-2200 ns), the interface blocks subsequent events while gating the appropriate ADC's and TAC's at the proper time. After a fixed dead time (determined by the maximum ADC conversion time), information as to which detectors had events is loaded into the status register which sends a LAM signal to the MBD. The MBD code first reads a status register which indicates which pair is to be read out, and the code reads out the ADC's corresponding to that pair, together with the corresponding TAC output. The code stores these three words in a 768 word buffer in the MBD memory, and when the buffer is full, its contents are transmitted to the PDP-11 central processor. A tape writing operation is initiated so that the words are written on a magnetic tape for further scanning. The MBD also writes three spectra directly into the megaword core: two total coincidence spectra for any two detectors, and the corresponding time spectra. Concurrent with the tape writing operation, the PDP 11 also does a sorting operation to produce 4 additional spectra. These spectra correspond to 2 pulse height and 2 time gates preselected by the operator. Thus true and accidental spectra may be produced for a given transition sequence and an adjacent pulse height region. The 7 spectra, 3 produced by the MBD and 4 by the PDP 11 allow the operator to monitor his experiment. All other combinations are produced later by off-line scanning of the event mode tape.

4) Channel 3 - tailored beam pulse height analyzer. The operation of the code is identical to that of the channel 0 analyzer, except for the high priority. This channel has been reserved for the tailored beam facility.

5) Channel 4 - TRISTAN multiscaler. This channel uses the same real time clock used by channel 1, except that 128 time channels (min. width 1/64 sec)

are available. Four CAMAC scalers are read and cleared at each clock interval, and the results accumulated by the MBD code in the megaword memory. After 128 clock cycles have elapsed, the analyzer is reset and waits for the next time sequence initiating trigger. The analyzer is used to trace out beta or delayed neutron decay curves.

6) Channel 5 - neutron time-of-flight analyzer. This analyzer is used for 2 parameter, pulse height versus neutron time-of-flight, experiments which are principally devoted to examining the radiative decay spectra from neutron resonances. The analyzer uses a commercially available time analyzer (Nuclear Data TOF/ND541) and the NDS-623 ADC. The time marker is derived from the ADC dead time pulse. The interface is shown schematically in figure 5.

The descriptors are read and stored in a 768 word MBD buffer, which is transmitted when full to the PDP 11. Two spectra, an overall 1024 channel time spectrum, and a 4096 channel pulse height spectrum are formed directly by the MBD in the megaword memory. The contents of the MBD buffer are operated in one of either two ways as desired. In the direct sort mode, the buffer is immediately sorted by the PDP 11 into 30 spectra, either time or pulse height, with preselected gates entered by the operator. In the tape mode, a tape of descriptor words is generated by the PDP 11 for later, off-line sorting. In most experiments, the direct sort mode may be used and the writing of event tapes may be eliminated.

7) Channel 6 - scalers/interlocks. The code corresponding to channel 6 reads in a set of 16 scalers which may be associated with any of the experiments outlined above. A 24 bit interlock word is also read. Each bit in this word may be associated with an interlock level set by some experimental condition. One example is a beam monitor interlock bit, which may be used to terminate an experiment when the beam falls below some acceptable intensity level. Scaler readings may be used for beam monitors, total event rates, clocks, or other

purposes. This channel is driven by a 1 sec pulse generator, so that these devices are read out at the rate of 1 Hz.

8) Channel 7 - control. This channel, with the highest priority is used to initialize parameters in the MBD code, and to initialize and enable the CAMAC dataway. The channel is also used to regulate control of the megaword memory, which can be accessed either by the MBD or by the PDP 11. A memory busy flag is set by this channel when the PDP 11 desires access to the memory. This flag prevents MBD accesses during that period.

The display and control features of the data acquisition code, which resides in the PDP 11, allow the operators to control and output the results of each experiment, as well as to make simple calculations of peak energies and areas. Provisions are included to output data in binary or alphanumeric form; the former provides rapid data in a format for the companion PDP 11/34A, while the latter format, in FORTRAN card images, may be easily read by any computer.

Considerable effort has been devoted to providing a means of accepting user commands so that use of the system is as simple as possible and each experimenter is protected as much as possible from incorrect syntax typing errors on his part or that of other experimenters. A format free I/O package has been developed such that each teletype line consists of blank delimited symbols. These symbols can consist of a 'command' vocabulary of mnemonic codes which are used to initiate various tasks and parameters which are decoded as alphanumeric symbols or as integer or real numbers. Input can be in response to a general prompt or in response to detailed questions asked by the system. Command lines are checked for validity, and for user convenience, drop out features provided. For example, 'LOOK PHA' sets system parameters to those associated with the 'PHA' channel. A 'DISP 3200 3600' would display channels 3200 to 3600 of the PHA spectrum with the vertical

scale chosen automatically. Addition of two more paramers to this line would override the automatic scaling, and just typing 'DISP' would update the previously displayed channels. Appendix I shows the commands which are available to the user.

Some additional remarks about the system should be made. The total system rate is limited to less than 10^4 events/sec. for spectral data. (There is no such limit for multiscaler data. That is set by the scaler speed which is typically 100 MHz for CAMAC scalers.) For multiparameter experiments this rate is perfectly adequate, but the collection of data in singles counting experiments is limited to several kHz. This limitation will shortly be removed by interfacing the ADC's to a CAMAC memory module via a controller module which performs the memory increment (histogram) operation automatically.

By relieving the CAMAC dataway, and the unibus, of the event traffic, the 10 kHz count rate limitation is removed. The limitation of count rate will then be just the digitization time for the ADC. For 200 MHz ADC's, which are commercially available, singles collection at 50 kHz with modest dead time corrections will be entirely feasible.

Data Reduction

A PDP 11/34A computer with two 5 megabyte disks, two 9 track 800/1600 bits/inch tape units and 128K of core storage acts as the data reduction computer in the two component system. In addition a VERSATEC matrix type printer/plotter and a VT55 display terminal is provided. The display terminal can be used in an interactive graphics mode. As in the case of the PDP 11/20 the DEC RT 11 monitor has been used.

Although each user is free to write his own reduction program, a set of data manipulation programs has been provided. Three main programs exist: DLK, PNLX, and LINAL.

These data analysis programs utilize the same format free input system that is used in the data acquisition system. The general structure of these programs are as follows. The computer accepts an input line from the terminal and decodes it into symbols. The first symbol is interpreted as a command and compared with a defined 'vocabulary' and branches to the appropriate section of code where any further parameters are decoded from the remaining symbols from that line and the function defined by that command performed. Additional information may be requested by the program. This structure, coupled with extensive overlaying, allows further data manipulation functions to be easily added.

The DLK program is a general data-array handling program which allows the transfer of data from tape to disk, or core (in either binary or BCD form), sets up displays, allows summing and shifting of spectra, scans event-mode recorded tapes, and megaword memory dumps, copies tape to tape, outputs spectra on tape for further processing, and lists spectra. The PNLX program provides extensive plot capability on the VERSATEC. Examples of PNLX plots are shown in the TRISTAN-produced spectra of figures 6 and 7.

The code, LINAL, extracts centroid and areas of γ -ray lines from spectra. Peak regions may be found and the resolution function determined with a method described in reference A. In the most sophisticated mode of usage each peak region is displayed, in order, for the user to set limits and initial positions for the peaks. The results of fitting those peaks (gaussians with tailing and steps^B) are displayed for the user with options of refitting or transfer

A. Marion L. Stelts and John C. Browne, Nucl. Inst. & Meth. 133, 35 (1976).

B. M. L. Stelts and R. E. Chrien, Nucl. Inst. & Meth. 155 (1978).

of results to hard copy and disk.

With the programs DLK, PNLX, and LINAL, the user has the minimum tools for spectral analysis. Other programs may readily be written by the user and added to the system. A number of user-written codes have been written and are present in the program library. One example is that of a complex decay curve analysis.

A final comment on the data reduction is that an enormous economy is effected in placing the tape scanning and graphical operations on a small computer, rather than using a central computing facility with a large scale IBM 360 series or CDC 7600 series computer. Most of these operations use simple algorithms which are well within the range of capability of the mini-computer. It is not a cost or time effective procedure to use a massive computer for such simple operations.

Table I. TRISTAN survey with 5.73 g ^{235}U in a neutron flux of 2×10^9 n/cm²/sec and ~30% transmission to tape collector.

Z	A	T _{1/2} (sec)	Saturation Activity dis/sec	Efficiency (%)
^{30}Zn	74	95	20	0.05
	75	10.2	9.0×10^2	0.8
	76	5.7	8.0×10^2	1.2
	77	1.4	2.0×10^3	1.0
	78	1.5	4.0×10^2	0.07
^{31}Ga	78	5.5	2.4×10^3	0.2
	80	1.7	1.6×10^3	0.1
	82	0.6	17	8×10^{-3}
^{32}Ge	80	29	2.2×10^3	5×10^{-3}
	82	4.6	7.4×10^2	4×10^{-3}
	83	1.9	1.4×10^2	2×10^{-3}
^{33}As	80	16	2.6×10^3	0.02
	82	19, 14	3.0×10^3	8×10^{-3}
	84	5.3	3.0×10^2	1×10^{-3}
^{35}Br	86	56	3.7×10^3	1×10^{-3}
^{36}Kr	90	32.3	1.2×10^5	0.02
	94	0.2	51	2×10^{-4}
^{37}Rb	94	2.7	1.7×10^3	5×10^{-4}
^{38}Sr	94	75	4.5×10^3	4×10^{-4}
^{47}Ag	114	4.5	6.8×10^3	0.33
	122	1.5	67	0.02
^{48}Cd	124	0.9	5.4×10^3	0.31
	126	0.5	1.7×10^3	0.20
^{49}In	124	3.2, 2.4	1.5×10^4	0.68
	126	1.5, 1.5	8.2×10^3	0.18
	128	0.9, 0.9	2.6×10^3	0.03
^{50}Sn	132	4.0	1.9×10^4	0.02
	134	1.0	1.1×10^3	0.03
^{51}Sb	132	168, 252	9.1×10^4	0.02
	134	10.4	8.5×10^2	6×10^{-4}
^{53}I	138	6.5	1.0×10^3	4×10^{-4}

Table II

<u>Channel/Priority</u>	<u>Function</u>
7	Control by PDP-11 Setup
6	Interlocks and scalers
5	Time-of-flight analyzer 2 parameter; energy and time
4	4 channel multiscaler 0.016 sec minimum time channel
3	pulse height analyzer tailored beam 3 crystal pair spectrometer - 8192 channel
2	multi parameter coincidence/ angular correlation table 8192 x 8192 x
1	γ -multispectrum analyzers 32 * 4096 channel spectra
0	auxiliary pulse height channels 8192 channels

Figure Captions

- Figure 1. Layout of the ISOL facility TRISTAN.
- Figure 2. Structure of the data acquisition and data analysis systems.
- Figure 3. Pulse height analyzer interface for Channel 0.
- Figure 4. Gamma-gamma-time coincidence analyzer interface for Channel 2.
- Figure 5. Neutron time-of-flight analyzer interface for Channel 5.
- Figure 6. PNLX plot of a portion of a TRISTAN produced gamma-ray spectrum taken at mass 78.
- Figure 7. PNLX plot of a portion of a TRISTAN produced gamma-ray spectrum taken at mass 128.

APPENDIX I

Instructions for DAC10

DAC10 is the current version of the data acquisition system servicing the pulse height analyzer (PHA), fast chopper (FC), filter beam (FB), gamma-gamma coincidence (GG), multiscale (MS), and spectral multiscale (GMS) channels. Experimental input is via Camac interfacing. Command input is via Teletype. Output is via two 9 track magnetic tape units. Spectra are stored in a megaword external memory. Event mode and dump tapes are recorded on unit 0. Data in external memory to be saved on tape are recorded on unit 1. Scalers and interlocks are implemented.

Note: The system will handle a maximum rate of about 10000 events/sec. If you approach this rate you will be contributing to the deadtime of other experiments. Check your rates before turning on your channel.

Input Formats:

The user will be prompted for input lines by A '*'. An input line consists of blank delimited symbols followed by (return). The general form is a command followed by parameters. For example:

DISP 200 600

would display channels 200 to 600. One or more blanks may delimit the symbols. Numbers must be limited to 10 digits, including sign and decimal point.

The program will respond with the date it was compiled and a list of channels implemented upon initialization.

The 'SET DIM' and 'SET RUN' commands should be used to initialize the dimensions and run numbers for the different channels. Use of the 'PRINT STATUS' command will give the initial values.

Experiment Control Commands:

Experimental control commands must be preceded by the appropriate 'LOOK' command.

CLEAR (FB, GG, PHA, MS, GMS, FC, S, STATUS)

If FB, GG, PHA, MS, or GMS is chosen, data acquisition is halted, the spectral storage areas for the experiment cleared, and the scalars zeroed.

CLEAR STATUS - Zeros the status words used to read the interlocks.

CLEAR S I - Clears the Ith (1-23) spectral storage area.

CLON (FB, GG, PHA, MS, GMS, FC)

Clears and starts data accumulation for the appropriate channel.

OFF (FB, GG, PHA, ETAPE, MS, GMS, FC)

OFF (FB, GG, PHA, MS, GMS, FC) stops data acquisition for the appropriate channel.

OFF ETAPE - stops data acquisition and event-storage on MT0 for GG or FC but writes no end of file on tape.

ON (FB, GG, PHA, ETAPE, MS, GMS, FC)

ON (FB, GG, PHA, MS, GMS, FC) - turns on data acquisition for appropriate channels.

ON ETAPE - initializes MT0 and starts data acquisition for GG or FC.

CONT ETAPE

Continues event mode recording for GG or FC or MT0 which had been previously interrupted by 'OFF ETAPE'.

ADD ETAPE

Continues event mode recording for GG or FC on MT0 which had been previously terminated by 'END ETAPE'. The tape is searched for an end of file mark, backspaced, and data recording resumed.

END ETAPE

Terminates GG or FC event mode recording on MT0 and writes a double end of file on tape.

Display and Output:

Display and list functions must be directed to the appropriate storage area in the external memory via a 'LOOK' command. Information on energy of a channel is available via the 'Q (EXP) X' command. Parameters are set via a 'SET.....' command.

Spectra are accumulated into areas of the external memory labeled 'FB', 'GG', 'PHA', 'MS', 'FC', and 'GMS'. 23 other storage areas labeled 'S 1-23' are available for temporary storage.

LOOK (?, FB, GG, PHA, MS, GMS, FC, S) (TIME, ENERGY, I) (I)

LOOK ? - Returns current look.

LOOK FB- Accesses FB.

LOOK GG T<IME> - Accesses GG time spectrum.

LOOK GG E<ENERGY> I- Accesses Ith GG energy spectrum.

1 E1 Total.

2 E2 Total.

3 E2 On-gate true.

4 E2 Off-gate true.

5 E2 On-gate accidental.

6 E2 Off-gate accidental.

LOOK PHA- Accesses PHA spectrum.

LOOK MS I - Accesses Ith (1-4) multiscale spectrum.

LOOK GMS I- Accesses Ith (1-33) spectral multiscale spectrum.
Spectrum 33 is the sum of the first 32.

LOOK FC I-	Accesses Ith (1-32)	F spectrum.
	1	T total.
	2	E total.
	3-(2+ITSC)	Scanned T spectrum.
	(3+ITSC)-(2+IESC)	Scanned E spectrum.
LOOKS S I-	Accesses Ith (1-23)	spectrum in the storage area.

SET (ETAPE, SCNLM, EGG, EFB, EPHA, EFC, EN, DIM, RUN)
Sets parameters for indicated functions.

SET ETAPE (GG, FC)-Selects event mode channel (GG or FC) to be recorded on tape. (GG is the default).

SET SCNLM (GG, FC)-Sets scan limits for (GG, FC).
 'GG' - Defines double-window (T,E1) scan-limits and tags to be set on for GG scans to produce E2-spectra. Program will query user for true time window. Accidental time window, on gate (E1), and off gate (E1). The gates may not overlap. True time descriptors must be less than the accidental time descriptors. The off-gate energy descriptors must be less than the on-gate descriptors.

'FC' - defines single-window (E or T) scan-limits and tags to be set on for FC scans to produce T or E spectra. The program will query E-windows (for T-spectra) first, T-windows (for E-spectra) next. The maximum total number of scans is 30. For each scan direction the window limits may not overlap except for the first one.

```
SET EGG I AGG BGG-Sets parameters for GG energy calibration
      for Ith detector
      EGG = AGG + BGG*X.
```

SET EFB AFB BFB SNFB - Sets parameters for FB energy calibration $EFB = AFB + BFB * X$, $EX = SNFB - EFB$.

SET EPHA APHA BPHA- Sets parameters for PHA energy calibration.
 EPHA = APHA + BPHA*X.

SET EFC AFC BFC -Sets parameters for FC gamma-energy calibration.
EFC = AFC + BFC*X.

SET EN RFP TPCB DELAYT- Sets parameters for FC neutron-energy calibration.
 RFP = Flight path (meters).
 TPCB = Time/channel (microseconds).
 DELAYT = Time of first channel (microseconds).

```
SET DIM NNNN (PHA, FB, GG, FC, MS, GMS, S) (E<NERGY> T<IME>)  
      <use 'PRINT STATUS' for current values>
```

Sets dimension for indicated channel to NNNN.
(T<IME> E<NERGY> apply only to GG and FC.)

'SET DIM' commands must be followed by 'LOOK' commands to be implemented.

SET RUN NNNN (PHA, FB, GG, FC, MS, GMS)
Sets run number for indicated channel to NNNN.

Q (EGG, EFB, EPHA, EFC, EN) X
Returns appropriate energy for channel X

DISP XMN XMX (YMN YMX)
Displays channels (XMN, XMX) with y-axis (YMN, YMX) if YMX = 0,
scale is automatically chosen.
DISP with no arguments updates the display.

Note: A maximum of 512 points may be displayed at any one
time. If more than 512 channels are requested
channels are grouped together and the channel with
the largest counts in each group is displayed.

MARK NNNN

Puts a marker on channel NNNN of the display, disables 'ECHO' on
the keyboard, and enables following display commands:

Q -Return to normal keyboard mode.
The other commands take the form of a signed
integer and an 'M' or 'I'. Let N = the integer.
NM Move marker N channels (+right, -left).
NI Intensify N channels to (right, left).
An area is computed for intensified channels
with a straight line background (from extreme
intensified channels) subtracted. A maximum of
64 channels (total) may be intensified.

Note: Display is not 'live'. The marker and intensified
channels are. Please don't complain about the
performance of this command unless the data acquisition
is off and you are displaying 512 channels or less.

L ISTART ISTOP

Lists channels (ISTART, ISTOP) with adjustment
to make START channel divisible by 10.

SAVE (TAPE,FTAPE)

Saves the spectrum chosen by preceeding 'LOOK' on MT1.
'TAPE' -Saves in BCD format.
'FTAPE' -Saves in binary format.

FCSAV (TAPE,FTAPE)

Saves all scans for FC channel on MT1 in (BCD, binary) format.
Program will query user for additional parameters.

DIR (TAPE,FTAPE)

Lists header records for all spectra stored on data
storage tape MT1 in (BCD, binary) format.

GET (TAPE, FTAPE) NAME

Reads spectrum identified by 'NAME' from MT1 to storage
area selected by 'LOOK'. (TAPE, FTAPE) selects (BCD,
binary) format.

DUMPX SA NREC

Dumps external memory in NREC records of 1024 words
(512 channels) each, starting at base address, SA
onto MTØ.

If SA is blank, then SA=BASC(2), NREC (NDCE(2)/512)*NDCT(2).

This dumps the memory used by the GMS channel.

PRINT (LOG, STATUS, SCNLM)

PRINT LOG-Prints contents of LOGFL.LOG on Teletype.

Used to maintain running record of important commands.

PRINT STATUS-Used to list status of data acquisition channels.

PRINT SCNLM-Prints scan limits set for FC channel.

Figure 1. Layout of the ISOL facility TRISTAN.

Figure 2. Structure of the data acquisition and data analysis systems.

ADC TO CAMAC INTERFACE

Figure 3. Pulse height analyzer interface for Channel 0.

EXPERIMENT

INTERFACE

CAMAC

Figure 4. Gamma-gamma-time coincidence analyzer interface for Channel 2.

* GL - GRADED LOOK-AT-ME, OPTIONAL MBD INTERRUPT

NOTE: DT = DEAD TIME-STARTS WHEN LOW LEVEL DISC. TRIGGERS

Figure 5. Neutron time-of-flight analyzer interface for Channel 5.

NAME = A=78/124

ID = A=78, 16 SEC COLL TIME, 300W

Figure 6. PNLX plot of a portion of a TRISTAN produced gamma-ray spectrum taken at mass 78.

NAME = A=128/IN

ID = A=128 ENHANCED FOR IN PROD, 10 S COLL, 1 S MOVE

Figure 7. PNLX plot of a portion of a TRISTAN produced gamma-ray spectrum taken at mass 128.