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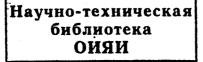
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I. Inrtoduction

The software of the $pi - e$ elastic scattering experiment was developed in 1970-71 by a team of physicists from the JINR (Dubna) and the University of California at Los Angeles (Los Angeles, Calif.) using the Hewlett Packard 2116B computer.

The experimental setup[1] consists of three groups of spark and proportional chambers [4].

The first group of five spark and two proportional chambers serves to detect the incident pi -mesons. The second group (seven spark chambers), the third group (six spark chambers), and an analyzing magnet comprise the wire spark chamber spectrometer. Scintillation counters and nanosecond electronics are used to trigger the chambers. Total absorption Čerenkov counters serve to identify scattered electrons. One event consists of 340 computer words. Three hundred of them are the coordinates from the spark chambers; eight are coordinates from the proportional chambers. Four are fast latches; thirteen are scalers; three are ADC's (Analog to Digital Converter); four are constant data; three are data from a digital voltmeter; four words are not used; and one word is for the event number.

II. Program Description

The programs can be divided into three groups. The first group includes MSR, RDOUT, DISK, TAPE. This set of programs basically controls the flow of data into the computer and out onto the magnetic tape. These programs are the highest priority, and are core-resident. The second group is an analysis package and is basically independent of the first group of programs, although it is scheduled by MSR in response to external commands by the experimenter. This group is controlled by ASR and includes TRFIT, FIDUK, HSTAC, DSPLY, (HSTGM, PLOTR, PLNUM), HTOPO (XPNUM, XPLOT), SPLOT, CONST,

SCPIO and PLBAK. This group is disk-resident. The third group consists of the following background programs: CHNGE, TCOPY, TSRDO and some others. There are some other special programs which will be considered in connection with the main ones. A brief description of the basic programs is given below.

1. MSR (Master Scheduling Routine)

This program is core-resident and has the highest priority in the system. It is controlled by the experimenter through a panel of push buttons. There are a total of 12 buttons, but only 8 are used: RUN, STOP, BEGIN RUN, END OF RUN, BEGIN SPILL, END SPILL, CLEAR RDOUT SYSTEM, RELEASE DISK TRACKS. MSR initiates the system operation. With this aim it is necessary to enter ON, MSR and to push the BEGIN RUN button. In this case, MSR schedules the program INIT to input constants and data. INIT schedules the program CHNGE to enter changes as well as the programs HSTAC and DISK with the parameters necessary to allocate disk memory for histograms and data. After finishing these operations we have a run of data flow which is controlled by MSR.

MSR is normally in a state of input-output suspension, waiting for a button to be pushed. When the register state is changed, (by the experimenter or by a signal from the accelerator) the program schedules the appripriate one. For example, when BEGIN SPILL is initiated by a signal from the accelerator, MSR schedules the program RDOUT for taking data. When pushing the STOP button, a tentative stop of the experiment takes place. A file mark is written onto magnetic tape by pressing the END RUN buttons.

2. RDOUT (Spark Chamber Readout Program)

This program controls the transfer of data from the readout /2/ into the core memory of the computer and out into magnetic tape. Data are transferred during the state of BEGIN SPILL into one of the core memory buffers that can store five events (1700 words). The contents of 329th and 335th words in the event are fixed test words. They are checked by the software and if found incorrect, the event is thrown out. After five events have been read, RDOUT schedules DISK to write a five event block onto disk memory. At the same time events are transferred and written onto the second buffer and also onto the disk by RDOUT. A total of 120 events can be written onto the disk. A counter EVSPL contains the number of events per spill.

When the END SPILL signal occurs, experimental data start to be written onto magnetic tape. A five event block is read off the disk to the core memory buffer. In addition, RDOUT accumulates various monitor scalers in core as events are read and schedules the program TAPE to write the block onto magnetic tape.

3. DISK

This program is used for writing experimental data onto disk. Eight tracks (the total number is 32), are allocated on the disk for writing 120 events. The pointer DTRAK contains the initial track number. The pointers CTRAK and PTRAK contain an address writing information onto the disk.

4. TAPE

This program writes magnetic tape. It is used mainly by RDOUT, but can be scheduled for any tape writing purpose. When calling TAPE, the address of the buffer, the number of words and the data type are indicated. This program is universal and can be scheduled by the other programs. It is also used by CONST and FIDUK.

5. ASR (Analysis Scheduling Routine)

This program is core-resident and is the lowest priority one (50). It masterminds all of the on-line analysis. It runs in an infinite loop looking for things to do. When it finds events to be analyzed it schedules the appropriate programs. Its actions are controlled through the pointer EVSPL. This program organizes reading in events (five event block) from the disk to the core memory buffer. The pointers TRKND and SECNO control reading in.

The data analysis programs TRFIT and FIDUK and the histogram accumulation program HSTAC are called for each block (buffer) of the experimental data. In addition, a switch of 16 bits (control panel, pointer TWS) is used to select particular histograms for display and printing and to select the following analysis features: PRINT - histogram printing; CLEAR - zeros the appropriate histogram; ZERO FIRST LAST - zero the lowest and highest bins of all histograms; SUPPRESS BIN SIZE ON PRINT - a key for presenting histograms as tables to be printed; PRINT FIDUCIAL HITS LAST 50 EVENTS - print fiducial hits from the spark chambers for the last 50 events; HOLD - stops accumulation of the selected histogram in display and print modes; PRINT SHORT SUMM - printing of accumulated scalers and their normalizations.

The control word (pointer TWS) contains a decimal number. Values 1 - 190 denote a histogram number; values 191 - 198 are used for the program HTOPO. HTOPO displays the spark and proportional chambers of the experimental setup in x or y views. The spark hit positions of an events are displayed on this layout, so that the topology of the event can be directly observed. The number 199 is used for scheduling the program SPLOT to display a two-dimensional diagram of the momentum distribution of events.

According to the state of the control panel, the program ASR prepares parameters and schedules required programs. A display pointer is exposed for a definite time (pointer DSCLK). After this time the picture is changed by a succeeding event.

During operation ASR continually checks the analysis flag. This flag can be turned on or turned off by the program MSR. The analysis flag is turned off during the BEGIN SPILL interval, and during the transfer of experimental data. The program begins operating again when END SPILL occurs.

6. TRFIT (Track Finding)

This program is disk-resident with priority 40. The program reconstructs the tracks of particles that have passed through the spark and proportional chambers, and selects pair events satisfying the kinematic criteria. This program is described in detail in ref. /3/

7. FIDUK (Fiducial Tracking Routine)

This program is disk-resident with priority 45. The program corrects fiducial constants in the spark chambers and updates them every 50 events. For each word of the chambers, the coefficient that changes the distance between fiducial signals (in "clock" counts) is calculated during the run relative to the initial value. The initial value is an absolute number of "clock" counts corresponding to the distance between fiducial wires. This coefficient is used in the program TRFIT.

8. HSTAC

This program is disk-resident with priority 45. The program accumulates histograms. The special calls of the program are the following: clearing of the whole buffer (4800 words) of histograms, "allocation" and "release" of disk memory. In the histogram accumulation case, the program reads the histogram array from the disk to the core memory. The array contains one two-dimensional and 191 one-dimensional histograms. The number of words and the address of each histogram are determined with the help of the array of HSTS control words. The number of words can change from 8 to 64. The array HSTGM contains information on the bin size of the histogram and on the absolute origin and mass of the histogram.

A list and types of the histograms are considered below in the item "Computer Output". Accumulation is performed for each event in the block (buffer). After completing the analysis of all events in the block, the histogram array is again written onto the disk.

At the beginning of each run all histograms are automatically cleared. During the run some histograms can be cleared on request from the control panel.

9. DSPLY

This program is disk-resident with priority 35. DSPLY is scheduled by the program ASR. This routine displays standard histograms on the 611 storage scope as determined by the thumb wheel switch. DSPLY uses the array of control words HSTS for determining the number of words and the address of the given histogram. Based on this information DSPLY read the appropriate histogram off the disk and displays it using the subroutines HSTGM, PLOTR and PLNUM. The display is linear with the maximum value plotted at the top and the bin size shown along the x-axis.

10. HTOPO (Topology Histogram)

This program is disk-resident with priority 35. This routine is calles by ASR. HTOPO dosplays a topological picture of the spark and proportional chambers for a single event. Eight views are possible; x and y views are displayed for each block of chambers. The first two are the first block of chambers, two for the second block, the next two for the third block and the fourth set of views is for all the blocks of chambers. HTOPO used the same subroutines as DSPLY: PLOTR and PLNUM. The array MISC includes data on the appropriate event. HTOPO treats information from the event for the chambers displayed. It gives their sizes, rotation, the number of sparks and their location along the beam (z-coordinates). PLOTR and PLNUM display these data. The display is updated every few seconds depending on the value set in the common location HTCLK. Using the

HOLD key of the control panel it is possible to display in turn all eight topological pictures of one and the same event. The choice of the topological picture is determined by the control panel (191-198).

11. SCPIO (Scope Output)
This program is core-resident with priority 32. It is called by the subroutines ERASE, MOVE and DRAW for preliminary erasing of a previous picture.

12. CONST
This program is disk-resident with priority 35. CONST writes a constant array onto magnetic tape: fiducial constants, fiducial separation constants, correction constants for the chambers and 21 constants of z-position of the chambers (along the beam). This is done at the beginning and end of every run. The call can be performed by the programs INIT, ASR and CHNGE.

13. PRINT (Printing Program for the Line Printer)
This program is used to print constants, histograms, monitor scaler information and the results of track finding on the line printer. PRINT is disk-resident in the background area. Its priority is 35. During a run this program can be scheduled by ASR and prints the information requested by the control panel. PRINT can be called by entering commands ON, PRINT, N on the teletype, where N is the input parameter of the program. It is possible to use up to five values of the parameter. The parameter value is a key for different output of the program. Number 1 means total summary (see the item "Computer Output"); 2 - prints the monitor scalers, normalization per spill and per beam and the results of track finding; 3 - prints the fiducial constants from the spark chambers; 4 is used for printing one histogram or more histograms; and 5 is used to print constants for track finding programs.
The pointer HSTS contains the address by which histograms are read off the disk. The COMMON blocks include the remaining data. PRINT uses the subroutines OPLST and OARAY to print one-dimensional and two-dimensional standard histograms.

14. CHNGE
This program enters changes. It is disk-resident in the background area. Its priority is 32. Before the beginning of the run CHNGE is scheduled by INIT to enter possible changes. Changes can be of different types and are divided into 22 groups. To enter changes for any group, it is necessary to type the command on the teletype. The commands to change are given below:

RUNUM	used to look at and if necessary change the run number.
FILNM	used to look at and if necessary change the file number.
OPR	used to look at and change the tape number and the operator numbers.
EVNUM	used to look at and if necessary change the event number.
MTCLK	used to change the time constant for HTOPO.
DSCLK	used to change the time constant for DSPLY.
SPCLK	used to change the time constant for SPLOT.
EDWND	fiducial window.
FIDUC	examines and changes fiducials.
FIDPR	array of current fiducials.
FIDSP	array of the distances between fiducial marks in "clock" counts for each plane.
CDPOS	correction constants for the chambers.
ZPOS	z-coordinates of the chamber (along the beam).
ORIGN	origin and bin size constants for histograms.
RATIO	the array of transformation constants used to convert delay line scaler values to spark coordinates.
MTAPE	used to position the tape forward or backward one file at a time.
FMARK	used to put END OF FILE mark onto magnetic tape.
TAPNO	used to change the magnetic tape number.
CONST	causes a number table to be written on tape.
PUNCH	used to punch the constant tape.
ZEUS	allows the operator to look at and if necessary change any location in the real time area of core.
/E	exits from change.

The first eight commands (except OPR) can change the contents of only one fixed word. The next eight commands (including OPR) change the contents of arrays. The remaining operators perform the test indicated in the description.

15. SPLOT
This program is used to display the two-dimensional histogram of the momentum distribution of scattered particles versus pulse height of the total absorption Čerenkov

counter. SPLOT is disk-resident with priority 35. The program reads the two-dimensional histogram array off the disk and schedules subroutines to prepare and display the data on the storage oscilloscope.

16. PLBAK

This program is disk-resident with priority 55. PLBAK is a special program to control the system of routines and external peripherals in the "off-line" mode. It is used to select and check constants, debug track finding programs and write selected events onto magnetic tape. The experimental information, read off the magnetic tape, is analyzed by appropriate programs controlled by ASR. The program is initiated by typing ON, PLBAK, N. For N =1 PLBAK initiates "off-line" analysis by initiating all arrays, etc., from the disk. The command $N = 0$ is used to continue analysis from one run on the magnetic tape to the next. In both the cases the program is used to position the tape forward or backward (files and records). PLBAK reads data off the tape to the core buffer, prepares control words for necessary routines, accumulates counts from the monitor scalers (RDOUT usually performs this) and schedules ASR to analyze programs and transfer results to the external devices. With the use of a flag PLBAK can write pair events onto magnetic tape. Further, this magnetic tape can be processed for a more detailed analysis by selecting events according to kinematic criteria.

17. TCOPY

This program is used to rewrite the contents from one magnetic tape to another one. TCOPY is controlled by the teletype with the help of special commands. The program is disk-resident in the background area. It works in the "off-line" mode.

18. TSRDO

This program checks the readout electronics of the experimental setup on-line with the computer. It is disk-resident in the background area.

III. Status Bits of the Programs

Status bits are used to control the scheduling of independent programs and the flow of data through the computer. All status

bits are contained in the two words FLGW1 and FLGW2 shown below.

FLGW1

Bits	Comments
0	flow of data by RDOUT = 1; dormant = 0.
1	PLBAK scheduled = 1; dormant = 0.
2	printing in TRFIT = 1; without printing = 0.
3	printing in PAIR = 1; without printing = 0.
4	FIDUK scheduled = 1; dormant = 0.
5	SCPIO scheduled = 1; dormant = 0.
6	Pair print flag
7	PRINT scheduled = 1; dormant = 0.
8	BEAM run = 1; normal run = 0.
9	no proportional chambers used in the TRFIT analysis = 1; with proportional chambers = 0.
10	use of kinematic conditions = 1; no conditions = 0.
11	run with pair events = 1; normal run = 0.
12	data for SPLOT.
13	data for SPLOT.
14	not used.
15	writing of pair events onto magnetic tape = 1; without writing = 0.

FLGW2

Bits	Comments
0	TRFIT scheduled = 1; dormant = 0.
1	ASR scheduled = 1; dormant = 0.
2	SPLOT scheduled = 1; dormant = 0.
3	BEAM on-line analysis = 1; normal = 0.
4	HTOPO scheduled = 1; dormant = 0.
5	condition key for PAIR.
6	DSPLY scheduled = 1; dormant = 0.
7	not used.
8	not used.
9	RDOUT scheduled = 1; dormant = 0.
10	TAPE scheduled = 1; dormant = 0.
11	data for ASR.
12	DISK scheduled = 1; dormant = 0.
13	panic flag for the readout = 1; normal = 0.

IV. Computer Output

The computer output is printed by the line printer and includes the run characteristics, track finding results, count sums by the monitor scalers and also 190 one-dimensional and one two-dimensional histograms.

The run characteristics are as follows: run number, file number on magnetic tape, number of triggers, spill number and number of events analyzed. The results of the events analysis are: the number of 0, 1, 2 and 3 track events in the three groups of chambers, and the total number of pair events found and the number that satisfy the kinematic criteria.

The monitor scaler sums contain information on the number of beam particles, various accidental coincidence combinations, and diverse coincidence sub-combinations of scintillation counters that participate in the trigger, as well as their ratio to the spill and beam numbers.

The two-dimensional histogram is used to calibrate the Čerenkov spectrometer. Along one of the axes the momentum of particles found by TRFIT is plotted. The pulse height (ADC channel number) is given along the second axis.

The one-dimensional histograms are described below.

1. This histogram contains information from the fast memory (latches).
2. This histogram contains the distribution of monitor scaler counts summed before each trigger.
3 - 5. These histograms contain the distribution of counts from the three ADC's.
6 - 7. These have the x and y coordinate distribution of primary particles in the proportinal chambers.
8 - 57. These histograms contain the spark distribution in each chamber in both views.
58 - 95. These views are the residual distributions for the spark and proportional chambers.
96 - 101. Give the χ^2 distribution of tracks in the three blocks of chambers in x and y views.
102 - 104. The momentum distributions of pair particles are displayed. The first histogram contains the momentum distribution of the low energy member of the pair, the second contains the

momentum distribution of the high energy member. The third histogram is the distribution of the momentum sum of the two pair particles. During a beam run this histogram gave the beam momentum distribution. This distribution is used to look at and control the beam parameters.

105 - 107. Not used.
108 - 111. These give the distribution of slope and intercept differences of straight lines between the second and third groups of the chambers in the center of the magnet in x and y views.
112 - 114. These show the x and y vertex distribution of the pairs, respectively.
115. Is the $\cos^2\theta$ distribution (coplanarity).
116. Is the distribution number of sparks per plane.
117 - 118. Is the frequency distribution for sparks in the proportional chambers for two, three, etc., neighbouring wires in x and y views, respectively.
119 - 170. Are the spark number distributions in each event for each chamber in both views.
171. Is the histogram of the chamber efficiency. Each bit corresponds to a definite chamber.
172 - 189. Are the chamber efficiency distributions as a function of spark chamber.
190. Gives the distribution of the logic number failing the analysis in TRFIT.

Control Panel (ASR)

Bits	Comments
0 - 8	The thumb wheel switch contains the histogram number.
9	PRINT
10	CLEAR
11	ZERO FIRST LAST
12	SUPPRESS BIN SIZE ON PRINT
13	PRINT FIDUCIAL HITS LAST 50 EVENTS
14	HOLD
15	PRINT CONSTANTS (print short sums)

Light Panel Bits (MSR)

Bits	Comments
0	not used·
1	not used
2	RUN
3	STOP
4	BEGIN RUN
5	END RUN
6	BEGIN SPILL
7	END SPILL
8	CLEAR RDOUT SYSTEM
9	RELEASE DISK TRACKS
10	not used
11	not used

References

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3. G.T.Adylov et al. JINR preprint, E1-6908, Dubna, 1973.
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