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COMPUTER-CONTROLLED DATA REDUCTION
OF SPARK CHAMBER FILM

Donald Zurlinden

July 27, 1967

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Contents

Abstract v
Introduction 1
Chamber Configuration Data 5
Main Program 9
FIDUCIAL Subroutine 9
LPEN, PLOT, and SCAN Subroutines 9
Fortran System Subroutines 10
Scanning Programs 10
Input-Output Subroutines 10
Subroutine for Scanning a Line 10
Subroutine for Finding a Fiducial 10
Subroutine for Finding Binary Data 11
Subroutine for Finding Tracks in Chamber 11
Controlling Program 13
Conclusions 15
Acknowledgments 15
Appendix
A. Definitions of an Opaque Area and a Spark 16
B. FRACTURED FLICKERS 19

COMPUTER-CONTROLLED DATA REDUCTION OF SPARK CHAMBER FILM

Donald H. Zurlinden

Lawrence Radiation Laboratory
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Berkeley, California

July 27, 1967

ABSTRACT

An automatic scanning and measuring system has been developed at the Lawrence Radiation Laboratory — Berkeley for the reduction of data from spark chamber film.

INTRODUCTION

The first LRL-developed automatic scanning and measuring system designed specifically for the reduction of data from spark chamber film has been in operation for approximately 6 months. The system, called SASS (Spark chamber Automatic Scanning System), was developed under the direction of Dr. LeRoy Kerth and Dr. Alan Clark of the Lawrence Radiation Laboratory at Berkeley, California. To facilitate this system, the setup for the initial run was designed and developed currently with the development of SASS. The purpose of the experiment is to study the production of dibosons (bound states of two π mesons or two K mesons) in reactions between π^- mesons and protons (Fig. 1). The experiment utilized the Bevatron's new external proton beam and spark chambers. By a system of mirrors and lenses, each view of each chamber is focused onto one frame of film. The experiment produced approximately 2 million events on film, which were scanned by SASS.

The SASS system consists of three major components; (a) a computer, (b) an on-line CRT film scanner, and (c) a set of computer programs to control the interaction between the computer and the scanning device.

The computer selected for this system was the DDP-24, manufactured by the Computer Control Corp. (see Fig. 2). It is a 24-bit machine with 8000 words of memory and a 5-microsecond memory cycle time. Attached to the computer is a typewriter, paper tape input-output, three Datamec tape units, and a Dec model 30 CRT display unit with light pen. Software delivered with the computer included a Fortran II compiler, machine language assembler, and a set of supporting subroutines. Extensive system programming was required to put these programs into a form suitable for use at LRL. A system editor and loader was written so that the programs could be stored on magnetic tape and called for by subroutine linkage or by a call from the typewriter. As programs were written and completed, they were edited onto the system tape.

The on-line CRT film scanner (see Fig. 3) consists of a precision CRT, a 35 mm film-transport mechanism, and a photomultiplier tube. Upon a command from the computer, the CRT proceeds to scan across a selected portion of its screen. Light from the precision CRT screen is focused onto the film by a lens. The light passes through the film and is focused on a photomultiplier tube. The signal from the photomultiplier tube indicates the optical density of the film. If the density has increased "sharply" from the previous points plotted, a data word is returned to the computer. This word consists of the intensity of the area and the distance from the start of the scan to the center of the area. The Dec 30 CRT operates in parallel with the precision CRT so that the scanned areas may be observed by the operator. A more detailed description of the on-line CRT film scanner may be found in: Raymond G. Kenyon, Berkeley On-Line Film Scanners, UCRL-17120, Sept. 1966.

This report describes the programs which control the interaction between the computer and the film-scanning device. Two sets of programs were written; the first set was a group of Fortran and machine-language programs used to define the configuration of the chambers in the SASS coordinate system; the second set was a group of machine-language programs

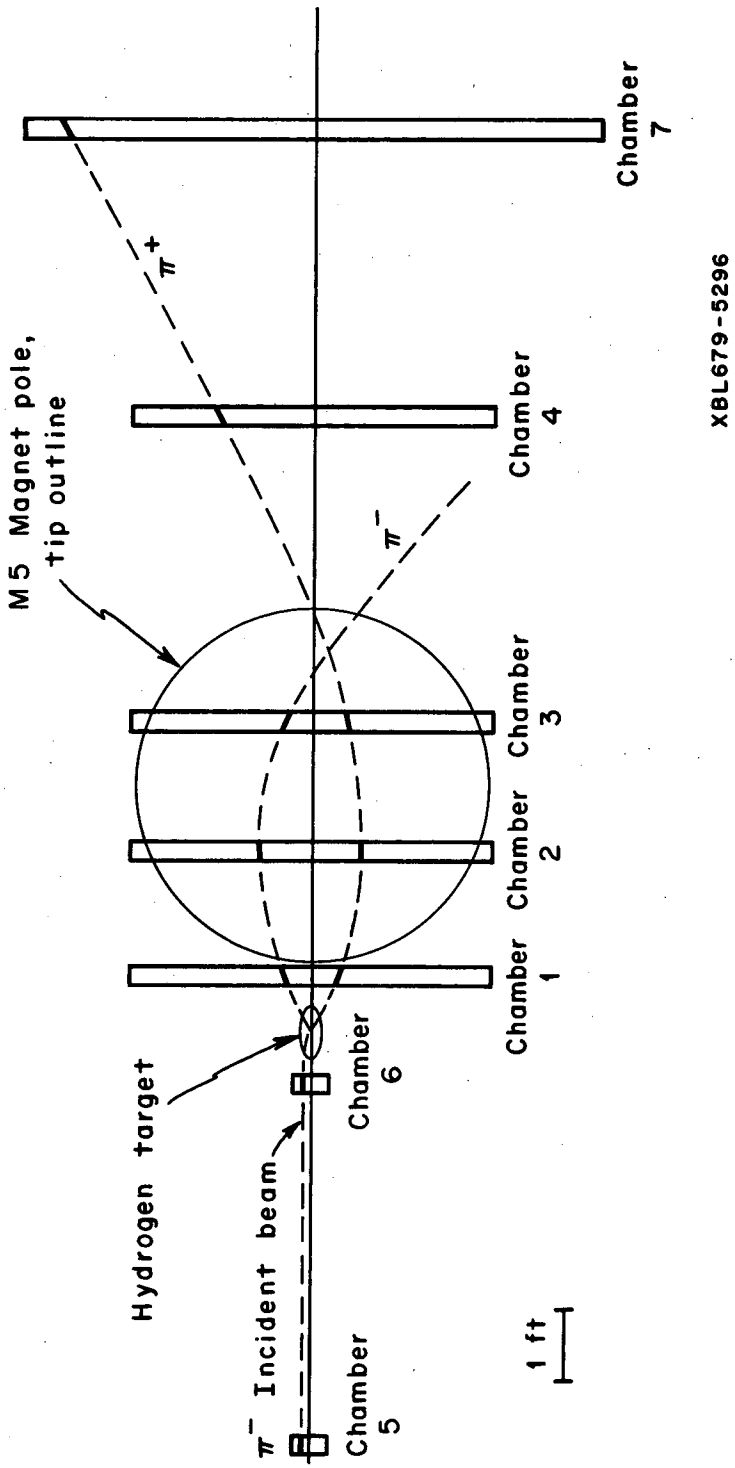


Fig. 1. Plan view of experiment (schematic).

XBB 677-3646

Fig. 2. DDP-24 computer.

Elec 4201

Fig. 3. On-line CRT film scanner.

used to scan the film and record the pertinent data.

CHAMBER CONFIGURATION DATA

What is obtained at the Bevatron is film which contains two kinds of frames: (1) grid-mark and (2) event data (see Figs. 4 and 5). The grid-mark information could also be called calibrating data. Recorded in each gap of a chamber is a series of marks whose position is known. In addition to being used later in the reconstruction of the data to real space, they are also used in eliminating errors created during the taking of data, i.e., errors caused by mirror distortions, movement of equipment, etc. In addition to the grid marks associated with the thirteen chambers used with this experiment, ten sets of further grid marks were placed near some of these chambers. These extra grid sets are scanned as ten one-gap chambers. The second type of information on film, event data, is the track data resulting from movement of nuclear particles through the spark chamber.

In addition to the above information, each frame contains a binary data box. The data are recorded as binary bits, with a 1 designated by the presence of a mark on the film. Two rows of binary data are recorded. The ends of each row of binary information are bounded by fiducial marks which are defined as the major fiducials of the chamber. Contained within the binary data are such variables as run number, frame number, hodoscope readings, etc.

Originally, the chambers were to be defined by fiducials in both grid mark and event frames. As later became apparent, it was impractical and unnecessary to have fiducials in each event frame, so that the chambers were defined by fiducial marks only the grid mark frames. The only fiducials on event data are the major fiducials.

The fiducial marks are dark circular spots on the film. It was decided that this type of fiducial was the easiest to record on film and, more important, that it would offer the fastest way of fixing the location of the mark on film. The chambers that contain event data are defined by three fiducials (see Fig. 6), which are designed in such a fashion that a line passing through fiducials 1 and 2 would intersect, at an approximate right angle, a line passing through fiducials 2 and 3. Since the gaps are parallel, it is simple to calculate for each gap the coordinates of a base point which is the origin of the scan. The base points are assigned a fixed distance away from the fiducials so that the fiducials will not be interpreted as a spark during the scan of the gap. Hence the necessary data to scan a chamber are the coordinates of the base points, the increments dx and dy, and the length of scan (number of increments). The gap width is defined as the distance between center lines of the gap plates and is necessary in the calculation of the base points. The corrected gap width is defined as the distance between the inside walls of a gap and is necessary for calculations during the side scan of a spark (i.e., the scanning parallel to and on either side of the original scan, in order to gain additional information on the spark profile for future analysis). Since the gap widths are constant and the gaps are parallel, we have a rectangular chamber coordinate system within the SASS coordinate system. In the chamber system, the abscissa is the gap number and the ordinate is the number of increments from the base point. During the scan of a chamber all calculations are done in the chamber coordinate system,

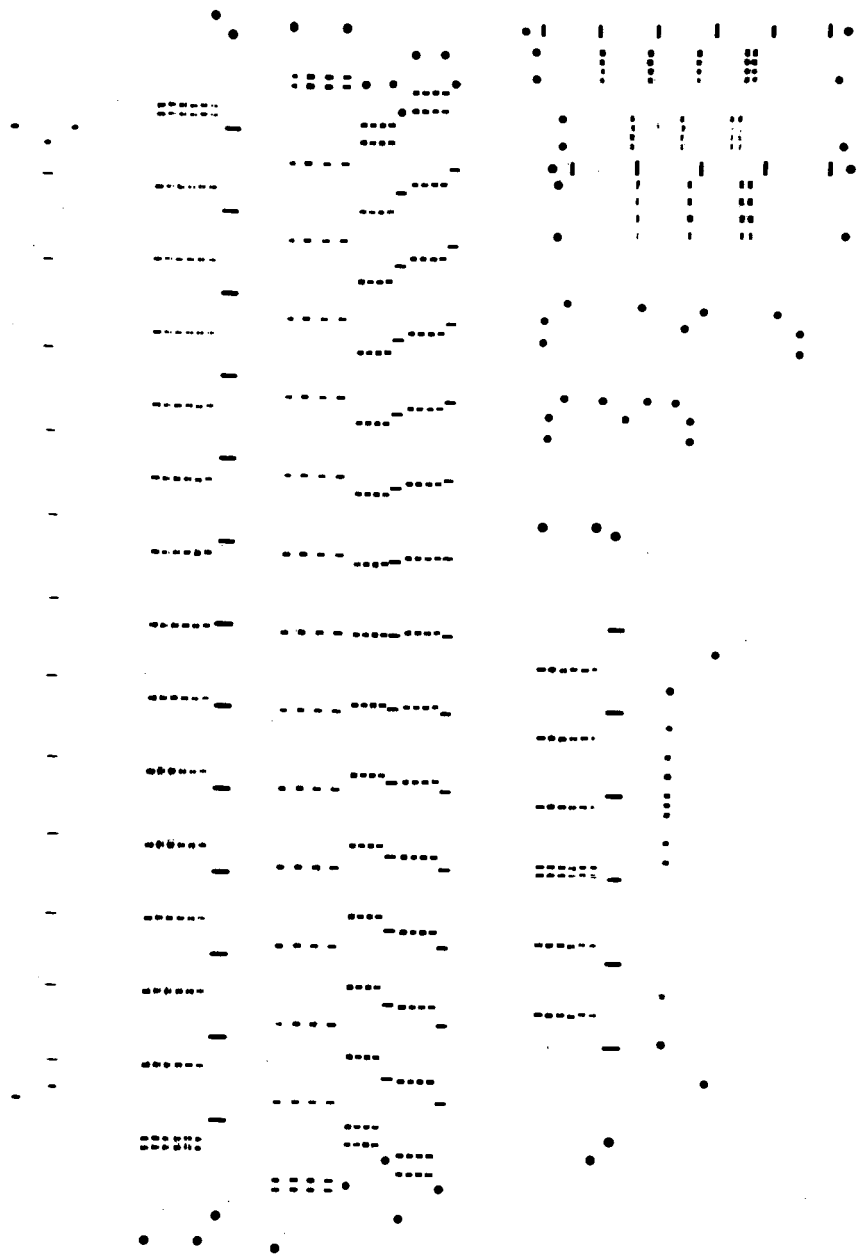


Fig. 4. Grid mark data.

Fig. 5. Event data.

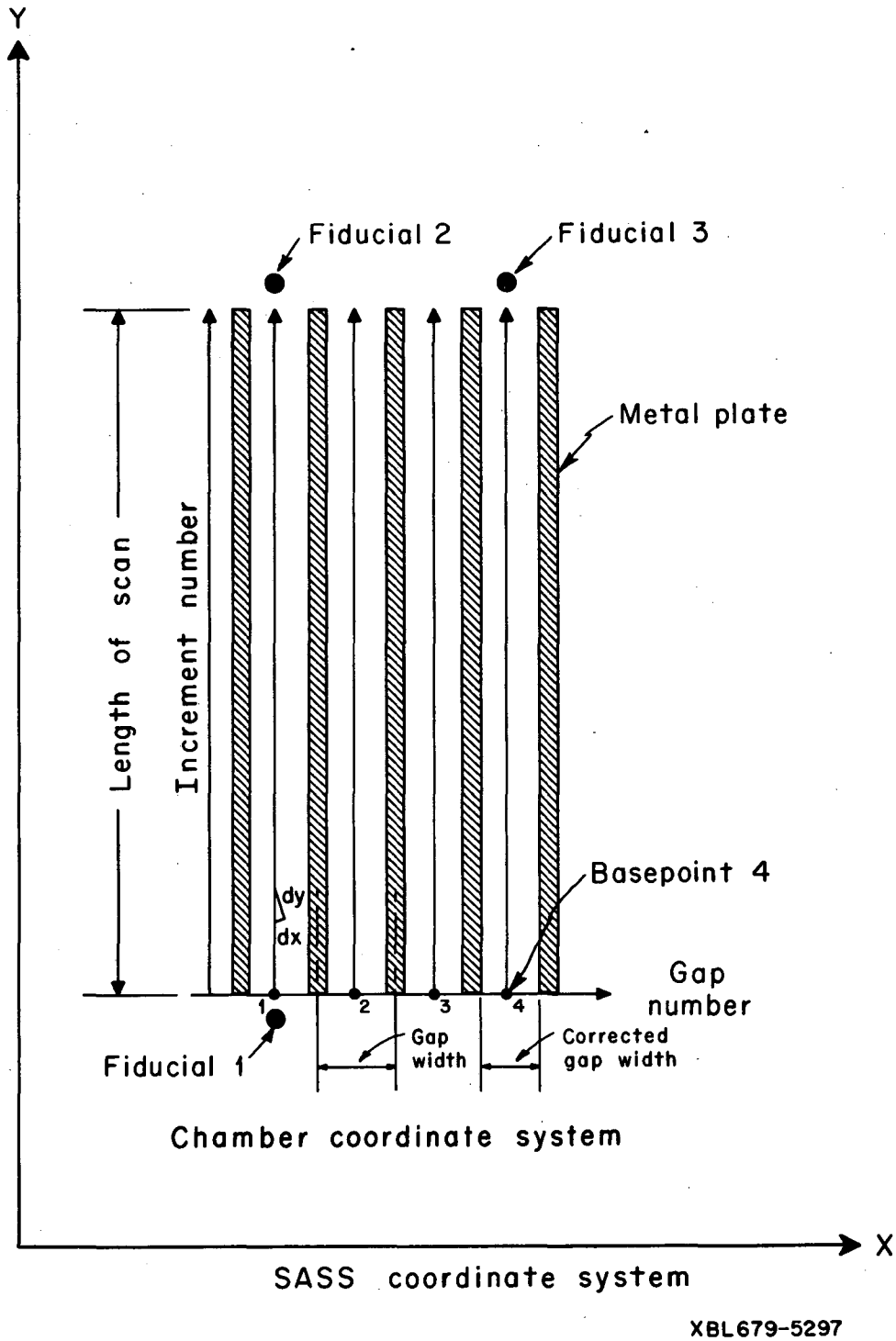


Fig. 6. SASS coordinate system.

except when the "CRT help" section (see below) is required. At this time, the data are expanded into the SASS coordinate system and displayed on the Dec 30 CRT.

The chambers used in this experiment contained either four or six gaps. The data for an event consist of two views each for six spark chambers and one view of a seventh chamber. The information was recorded on the film in groups of runs; within the runs are series of events. Each run is defined by a set of experimental parameters, and consists of grid-mark data followed by the series of events with the grid-mark data repeated as the last frame for the run.

A set of programs on configuration data was written for the purpose of determining the position of the spark chambers on the film. Constants within the program include such items as the number of gaps for each chamber, the number of grid marks in each gap within each chamber, and minimum and maximum number of hits to make a grid-mark success. The film is positioned at a grid-mark frame, and by using a light pen on the screen, the operator can select any portion of the film he wants scanned. The program scans a portion of the film defined by the operator and displays this information on the Dec 30 CRT. The operator then picks out the pertinent fiducials with the light pen, and the computer records them. This process is continued until the major fiducials and the fiducials defining all the chambers are completed. When all fiducials have been defined, the chamber configuration data are punched in paper tape. The paper tape is used as the input medium to the scanning routines, and is reused for all films made in the same configuration.

Since time is not a main concern during the running of the chamber configuration setup program, Fortran (which runs slowly) was used wherever possible to simplify the task. A list and partial description of the programs follows:

MAIN PROGRAM

The main program is written in Fortran. It includes the chamber configuration constants and controlls the flow of input from the typewriter, Dec 30 CRT, and film-scanning device to output on paper tape.

FIDUCIAL Subroutine

This subroutine is written in Fortran, and its purpose is to scan sections of the film as defined by the operator and control the flow of input and output to the LPEN, PLOT, SCAN, and FIDUCIAL FINDER subroutines. the FIDUCIAL FINDER subroutine is described in the Scanning Programs Section.

LPEN, PLOT, and SCAN Subroutines

These machine language programs were written in the initial stages of development of SASS for use as diagnostic aids in debugging the computer and film-scanning device. The purpose of these programs is to scan film, display points on the Dec 30 CRT, allow the operator to pick out desired

points by use of a light pen, and return with information defining the hits or midpoints of opaque areas.

Fortran System Subroutines

The remainder of the chamber configuration setup system consists of the necessary Fortran support routines such as ABS, SIGN, SQRT, etc.

SCANNING PROGRAMS

Since time is important during the scanning of successive frames of data, all programs were written in machine language with an attempt to make the routines operate as fast as possible. A description of the scanning routines follows.

Input-Output Subroutines

Four routines were written to perform input output functions as follows:

(1) Input data to storage via the typewriter.
(2) Output data from storage via the typewriter.
(3) Punch or read data to or from the paper tape.
(4) Output data from storage via a magnetic tape.

These programs contain the necessary checking and recovery procedures for abnormal equipment functions.

Subroutine for Scanning a Line

A subroutine called SAWS (Scan Along With SASS) is the communication link between the film-scanning device and the computer. All programs that scan film use this subroutine. From the given input, which defines the gap, a scan across the film is made. When the film scanning device notes a dark portion of the film (this is defined as a hit), the number of increments from the origin of the scan and the intensity of the hit are recorded. When the scan is completed, the program computes the midpoint, width, and intensity of the opaque area (see Appendix A for definition of an opaque area). A minimum-maximum width criterion is used to decide if the defining data for the area are to be saved or ignored as noise. SAWS eliminates dark areas with widths greater than the defined maximum. On completion of the program, the output buffers contain defining information for all the hits and midpoints.

Subroutine for Finding a Fiducial (FIDUCIAL FINDER)

The purpose of this subroutine is to accurately locate the center of a circular fiducial spot on the film. The calling program transmits the approximate x and y coordinates of the fiducial. This subroutine finds the center of the fiducial and returns, or if it cannot find the fiducial returns with an answer of zero. The method used is to first do a horizontal scan across the area of the fiducial using the subroutine SAWS. The subroutine discriminates against noise by requiring that each spot crossed by the scan line be between

a minimum and a maximum width. If the first horizontal scan does not cross the fiducial, scans are made above and below the original y coordinate to see if the fiducial can be found. If it cannot be found, the routine returns with an answer of zero, indicating that the fiducial was not in the position indicated. As soon as a scan does cross the fiducial, two vertical scans are made, one to the left and one to the right of the midpoint of the dark area found in the horizontal scan. The average of the midpoints of these two vertical scans is taken as the y coordinate of the fiducial. After the y coordinate of the fiducial has been located, a horizontal scan is made above and below this y coordinate. The midpoint of these two scans is averaged and taken as the x coordinate of the fiducial. If, during the vertical scans, no spot is found on a line, the x coordinate is set 1 SASS unit closer to the fiducial and a rescan is made. This is continued up to nine times. If after nine tries no spot has been found, the subroutine gives up and says there is no fiducial here. The same technique is used during the horizontal scan.

Subroutine for Finding Binary Data

The purpose of this subroutine is to read the binary number from the data box on the film. The data box contains two rows of lights, with thirty lights in each row. These two rows of lights are located between the four major fiducials on the film. This subroutine is called, giving it the location of a table which contains the location of these four major fiducials. Provisions have been made whereby any one of the four fiducials can be missing but proper operation of the subroutine is still possible. Missing fiducials are indicated by coordinates equal to zero. Assembled into this subroutine are constants giving the relative locations of the four major fiducials and the relative locations of these lights with respect to the fiducials. Using this information, the subroutine calculates the length and direction of a line that will scan across the center of the row of lights. The first row of lights is scanned and the coordinates of all hits stored in a table. Noise is discriminated against by requiring that the area for each light be between a minimum and a maximum width. After the scan is completed, the table of midpoints is examined one point at a time, and a calculation is made to determine which light the point corresponds to. As each point is examined, the appropriate bit in a 30-bit word is set. The second row is scanned and processed similarly. The subroutine then stores in a table specified in the calling sequence the two 30-bit words found and returns.

Subroutine for Finding-Tracks-in-Chamber

The largest subroutine in the system is FTIC (Find Tracks In Chamber). The purpose of the program is to scan through a chamber and return with data which define the tracks in the chamber. The chamber coordinate system is used. The input to this program is the configuration data for the chamber. Using the subroutine SAWS, FTIC scans down the center line of one gap after the other, storing the midpoints, intensity, and width of each spark found in the gap. If it becomes apparent that not enough gaps contain information to define a track, then the routine returns with an answer of zero. If sufficient gaps contain information, then the sparks are sorted into tracks.

The original method for sorting the points (sparks) was the point-by-point prediction method. If was assumed that the film would contain all the

sparks of a trail with only a few extraneous dark areas, and that the point prediction method would be sufficient. In this method, point 1 in gap 1 is connected to point 1 in gap 2. If the slope of the line connecting these two points is in the proper range, then the line is used to predict where the point in the next gap should be. An interval about this point is searched, and if the point is found, it is connected with the first point in the first gap and a new line is constructed. This new line then predicts where the point in the next gap is. This predicting continues until all the gaps have been searched or it becomes apparent that no track will result from this procedure. This process is repeated until all the points in gap 1 are connected to the points in gap 2. If no points are found in gap 1, then gap 2 is treated as the first gap, and the prediction method proceeds from there. On completion of the search, a test is made to determine if more than one track contains the same point. If the test is negative, the program proceeds to the side scan section, but if the test was positive, the program proceeds to the CRT help section.

When the CRT help section is called, all data which resulted from the scan of the chamber are displayed on the Dec 30 CRT screen. The operator then consults the original film displayed in magnified form on a film projection screen and decides if this event is worth further study. If not, then by sense-switch control, the program exists, but if the operator deems this event worth following further, then by use of a light pen he indicates the points which in his mind define the correct tracks. The data for these tracks are stored and program continues to the side scan section.

Since the spark images are not necessarily rectangular in shape, it is necessary to make a side scan to find as much information about the contour of these sparks as possible so that this information may be used later during the pairing of the tracks into three-dimensional space. To accomplish this, the program does a side scan of length equal to twice the spark width on each side of the original point, combining the information from the original scan to result in a final average intensity, spark width, and distance from base point (see Appendix A for definition of spark). The program exits to the calling routine.

The quality of the film did not come up to expectations, but rather had blanks or extraneous sparks. This resulted in the computer's spending more than half the time in the CRT help section. Consequently an additional procedure was included when duplicate sparks were found after the search.

The procedure for processing tracks with duplicate sparks is as follows: A χ^2 is calculated for tracks which contain the most points. The track with the most points and the smallest χ^2 is stored, and its points are flagged. The next track with the most points and the next-least χ^2 is stored, and its points flagged. During this process, any track whose points were used in previously stored tracks are ignored; i.e., prior to the χ^2 calculation, it is determined if any points in this track were used in previously stored tracks. If so, these tracks are ignored, and the χ^2 is not calculated. This procedure is continued until all the tracks have been processed and the data stored or ignored, whichever has been the case. If at the end of the χ^2 test there are more than the acceptable number of tracks, an error exit is made, otherwise the flags are examined to ascertain if any points were used in the original search for tracks but were left over after the χ^2 test was completed. If there is a sufficient number of gaps containing these sparks to make a track,

then the program tests to determine if there is a greater number of sparks in the chamber than permissible; if so, an error exit is made, otherwise the program proceeds to the CRT help section. If the number of gaps containing sparks is less than that required to make a track, the program continues to the side scan.

By introducing the χ^2 tests into the program, the number of frames requiring CRT help was reduced to approximately 5% of all frames. The reason that some time was being spent in the CRT help section was still due to combinations of tracks caused by extraneous and missing sparks in the gaps and intersecting tracks.

In an attempt to keep the program out of the help section, new techniques were analyzed and tested, and one was finally adopted to replace the point-by-point search section in the program. The principle of the new searching method was to use the sparks in the end gaps of the chambers as reference points for a hypothetical band width running through the chamber. Then any points in a gap that fell in this band width were accepted, and all possible combinations of tracks were made from these. The slope of the line connecting the end points must be within a specified limits in order that the band width be calculated. All possible combinations of the points in the end gaps are used, and a table is kept which records each track the point is used in. Since it is possible for sparks to be missing from tracks, the data from all combinations of gaps are investigated as possible reference points for a band width. When two reference points have been selected, it is determined whether both points have been used in the same previous track, and if so, they are ignored. On completion of the search, a test is made to determine if more than one track contains the same point. If the test is negative, the program proceeds to the side scan section, but if the test was positive, the program proceeds to the χ^2 test section. The χ^2 testing and help section remained the same. It was found from this technique that we reduced the number of frames requiring help to approximately 2% of all frames. The program was shortened, and the overall logic simplified. The time used for good events remained about the same.

CONTROLLING PROGRAM

The procedure for scanning film consists of an initial setup of the data defining the chambers and the subsequent scan of the run. Since up to 6 hours may be required to scan a run, the controlling program was designed so that it was possible to sign on and sign off at any time during the scan of a run. When a new operator "signs on", the data defining the chambers are read in from paper tape and written on magnetic tape. The operator types in the date, time, run number, and operator's initials, and the program proceeds to scan each frame in the run.

A Flight Research camera was used at the Bevatron. Both the camera and the film transport mechanism use a pin registration method so that the only changes in chamber position from frame to frame are displacements in the vertical and horizontal directions. There is no rotation; consequently, only simple additions are required to prepare the necessary data for scanning. The corrections for each frame are found by scanning the major fiducials and comparing their coordinates with those read in with the configuration data.

The differences are applied to the chamber base points from the configuration data to yield corrected chamber base points. After the major fiducials have been scanned, the data box is scanned and the information is recorded in memory. A check is made to determine if the data box contains the proper run and event number; if not, the operator is alerted via the typewriter. The output from the binary data box together with the sign-on data, signature, and major fiducial corrections is stored in buffers preceding in memory those used for grid-mark or event data, and is written on magnetic tape at the same time as the grid-mark or event data are written.

One of the bits in the binary data box determines whether the frame contains grid-mark or event data. If the bit designates the frame as grid-mark data, the fiducials for each of the chambers are scanned and checked to determine if their positions are correct. The 13 chambers and ten "one-gap chamber" being scanned gap by gap. If the number of grid marks in the gap is less than the prescribed amount, the rest of the buffers are filled with zeros, and the next gap is scanned. If more than the permissible number of grid marks is found, then the chamber number, gap number, and number of grid marks are typed out on the typewriter. The buffer then accepts only the first n values of grid marks, where n is the permissible number. When all chambers have been scanned, the data are written on magnetic tape and the program stops. By sense-switch control, the film is advanced to the next frame, and the program continues or the operator signs off.

If the binary data box indicates that this is an event-data frame, then the output buffers are cleared, and event scanning is initiated. Twenty-eight lights in the binary data box are each associated with a single counter in the hodoscope used in the experiment. One and only one of these scintillation counters can be triggered for each event. If more or less than one bit is indicated, the event is rejected. The program begins scanning with the first chamber. If the scan of a chamber results in more than the maximum number of tracks permissible for that chamber, the event is immediately rejected. Each view of the chambers 1 through 4 is scanned. After each view of the chamber is scanned, a test is made to determine if both views have the same number of tracks. If the test is negative, the event is rejected. Because of the location of chambers 1 through 4 and the nature of the experiment, only certain event configurations are possible. The different permissible configurations are assigned signatures (consisting of a four-digit number, each digit indicating the number of tracks in chambers 1 through 4), and stored in a table. During the scan through chambers 1 through 4, a signature of tracks in each chamber is constructed and compared with those permissible signatures in the table. If the comparison fails, the event is rejected. If the chambers 1 through 4 were successfully scanned, each view of the incident-beam chambers (5 and 6) is scanned. The event is rejected if both views of the beam chambers do not have one and only one track. The decision to scan the one view of the seventh chamber is dependent upon the presence or absence of a light in the binary data box. When an event is rejected, it is assigned a reject code which indicates the reason for rejection, and the program proceeds to scan the next frame. If the event was good, the event data are written on magnetic tape, and the film is advanced to the next frame. Numbers designating the frames rejected and the frames recorded are kept in a statistics table.

The program continues scanning until either the grid-mark frame at the end of the run is scanned or the operator by sense-switch control signs off. When the sign-off occurs, statistics for this run are printed on the typewriter. The results from SASS are used later in a detailed analysis of the nuclear phenomena involved. The scanning programs use approximately 70% of the 8000-word memory.

CONCLUSIONS

Approximately two million frames have been scanned at a rate of about 4 seconds per frame. The best previously available semiautomatic measuring device measured at a rate of about 4 minutes per frame.

For a system such as SASS to be successful, it is very important that the characteristics of the scanning system be considered during the design and construction of the experiment. The ease of programming and the computer time per event are dependent upon the condition of the data on film.

ACKNOWLEDGMENTS

The development and design of the on-line CRT film scanner was carried out by Ray Kenyon, Gene Binal, Paul Broadhead, and Dave Gumz. In addition to writing and documenting the two subroutines FIDUCIAL FINDER and BINARY DATA SCAN, Bob Belshe carried out extensive system programming and engineering consultation on the entire system. Technicians operating the machine during the initial debugging period included Dave Perry and Fred Terwilliger.

This work was done under the auspices of the U. S. Atomic Energy Commission.

APPENDIX A:

Definitions of an Opaque Area and a Spark

An opaque area may be a fiducial mark, binary data mark, grid mark, or spark track. The area which describes binary data or grid marks is scanned once. The method of scanning a fiducial mark is described in its respective section of this report. The area of a spark is scanned once on each side of an original scan. The following describes the data resulting from the scan of an opaque area. The coordinates of a base point (x, y), a set of increments (dx, dy), and the number of increments (L) are required by the film-scanning device in order to locate an opaque area. When the scan is passing through the area, a hit is recorded for each increment, and a word, which contains the intensity and number of increments, p, from the origin of the scan is sent to the computer, where $0 \leq p \leq L$. The SASS coordinates of the hit can be obtained from the relation

$$X = x_b + p \cdot dx, \quad Y = y_b + p \cdot dy.$$

Let:
- m = number of scans,
- j = scan number ($j = 1, 2, \cdots m$),
- n_j = number of hits in opaque area for scan j,
- i = hit number ($i = 1, 2, \cdots, n_j$),
- d_{ij} = intensity of hit i for scan j,
- p_{ij} = distance of hit i from base point for scan j,
- min = minimum number of hits to define an area,
- max = maximum number of hits to define an area.

SAWS Output

If $\min \leq n_j \leq \max$ is satisfied, the output from SAWS which defines an opaque area for scan j is

$$I_j \text{ (average intensity of hits)} = \sum_{i=1}^{n_j} d_{ij} \Big/ n_j$$

$$W_j \text{ (width)} = n_j,$$

$$D_j \text{ (distance from origin to center of area)} = \sum_{i=1}^{n_j} p_{ij} \Big/ n_j .$$

The output data are scaled one binary place and are stored in one word as follows:

Bits 1 through 4: I_j
5 through 12: W_j
13 through 24: D_j, where bit 1 is the sign bit.

FTIC Output

On completion of side scans of a spark, the output from FTIC, which defines the spark, is

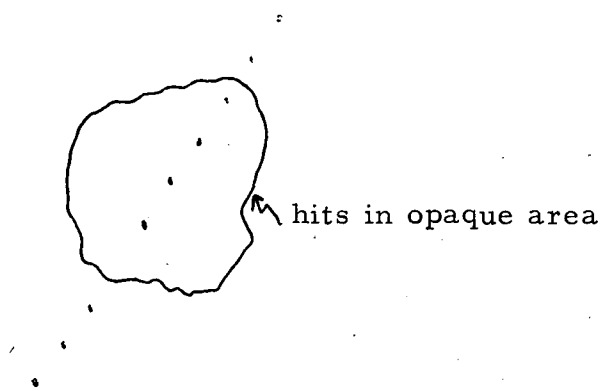
$$\overline{I} = \text{average intensity of all hits} = \sum_{j=1}^{m} I_j n_j \Big/ \sum_{j=1}^{m} n_j = \sum_{j=1}^{m} \sum_{i=1}^{n_j} d_{ij} \Big/ \sum_{j=1}^{m} n_j ,$$

$$\overline{W} = \text{average width of scans} = \sum_{j=1}^{m} n_j \Big/ m ,$$

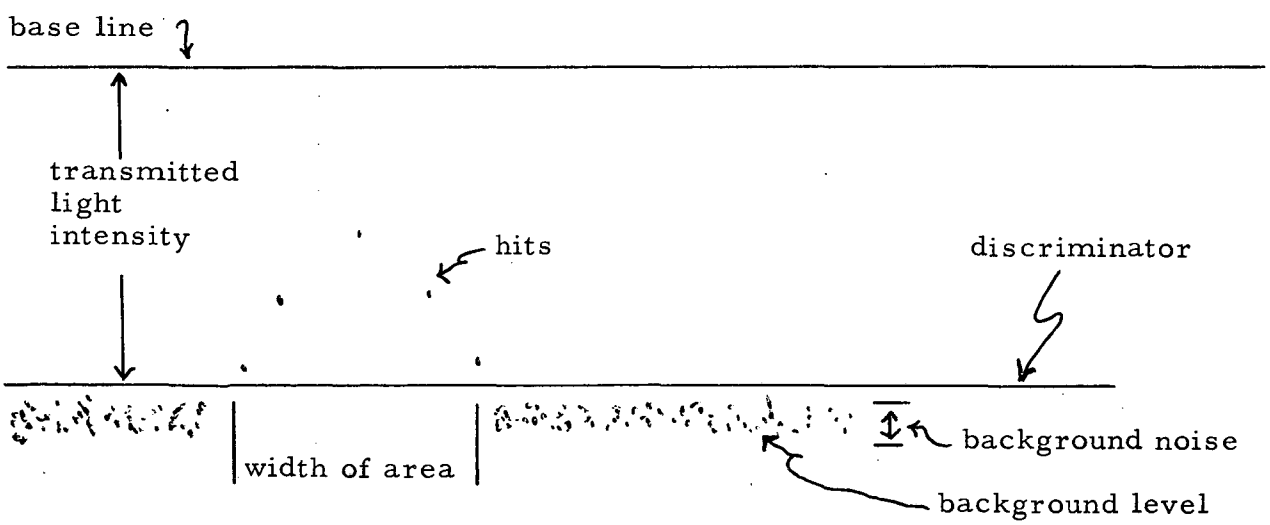
$$\overline{D} = \text{average distance of scans} = \sum_{j=1}^{m} D_j \Big/ m .$$

The output data are scaled one binary place and stored in a word with the same bit pattern as SAWS output. The desired output with respect to intensity would be the average of the sum of the intensity for each scan, but since this format would not fit in the four bits assigned to intensity, the above definition of intensity was used. This choice required that the analysis programs compute the average of the sum of the intensity for each scan by calculating the product $\overline{I} \cdot \overline{W}$.

Scan as seen on film



Scan as seen on oscilloscope looking at photomultiplier signal



APPENDIX B:

PROGRAM FRACTURED FLICKERS

Assembled Parameters and Conditions
(in SASS units)

1. min number of hits to make a fiducial = 15; max = 40
2. length of initial fiducial scan = 110
3. length of succeeding fiducial scans = 60
4. maximum distance for fiducials to move in either x or y from original setup = 5
5. min number of hits to make a binary = 5; max = 30
6. maximum number of hits in scan for binary data = 400
7. maximum number of midpoints in scan for binary data = 80
8. maximum number of gaps per chamber = 6
9. min number of hits to make a grid mark = 6; max = 64
10. maximum number of hits in a gap for grid marks = 1000
11. maximum number of midpoints in a gap for grid marks = 20
12. min number of hits to make a spark = 4; max = 104
13. maximum number of hits in a gap for event data = 500
14. maximum number of midpoints in a gap for event data = 10
15. maximum number of possible tracks in chamber = 20
16. maximum number of resolved tracks per chamber = 3
17. maximum number of words of track data per gap = 18
18. permissible interval about predicted point = ± 1/2 gap width
19. permissible slope about adjacent point = 0.5
20. number of side scans = 1 on each side
21. length of side scan = 2* width of spark

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