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Authors
White, Howard S.
Britton, Barbara
Franz, Joan
et al.

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University of California
Berkeley, California

ABSTRACT

DAPR is a system which has been developed at Lawrence Radiation Laboratory for Digital Automatic Pattern Recognition in bubble chamber pictures. Pictures are measured by the Flying Spot Digitizer, and the data are reduced to yield a data abstract tape. This tape has, for each track found within each picture, precision points representing its locus, and a measurement of bubble density. The tape also has a short table specifying the spatial vertices and their constituent tracks in the three views. The data abstract tape may be rapidly scanned by a computer program; this program, without manual assistance or further reference to the film, yields an output tape containing selected events edited into a format suitable for processing by a standard geometry program.

DAPR has been operated on five rolls of film from a 6 Gev/c proton exposure in the LRL 72" HBC. This relatively difficult practice experiment was chosen as being the worst typical case which DAPR might soon face in actual physics experiments. A few representative frames are discussed in detail, and an analysis of the results of the entirely automatic DAPR scan for 4-prong events is given. These results are compared with the manual scan which was made as part of the HAZE processing of that experiment.

The comparison of DAPR and manual scanning is very encouraging. While certain additions are needed to the degree of sophistication in parts of the system's logic, these are few in number and clear in concept. Even now the throughput of events is higher than was that of HAZE when physics production began. No mass of indistinguishable fake events contaminate the data. We believe therefore that DAPR stands at the threshold of doing actual physics experiments.

The DAPR system for Digital Automatic Pattern Recognition of events in bubble chamber pictures has incorporated the earlier prototype track following programs. These were developed in a collaboration between the Pasta, Marr and Rabinowitz team at Brookhaven (Ref. 1), and members of the Data Handling Group at Berkeley (Ref. 2). These early developments demonstrated that a computer like the IBM 7094 could associate digitizings produced by a Hough-Powell Device, and reduce them into lists of master points that accurately and completely represent all important track segments in a bubble chamber photograph. They further demonstrated that the computing process could be carried out fast enough to economically justify the operation.

The DAPR system at Berkeley is divided into two main phases for processing the information in the bubble chamber film. The first phase has as its objective the production of a magnetic tape containing a digital representation of position and bubble density information for each track in every picture. This Data Abstract Tape (DAT) therefore contains all of the usable information from the film, but in a form most readily accessible to a digital computer. It may be thought of as being an analog-to-digital conversion of the film information. No further reference to the film is necessary; subsequent access is made to information in the DAT.

The second phase of processing uses a computer program to scan the pictures described in the DAT, and to write as output a tape containing the selected events in a form suitable for presentation to a standard geometry program. Since the input is optimal for use by a digital computer, this scanning phase goes extremely fast. It is therefore feasible to select one or two most interesting event types for immediate consideration, or to easily rescan with revised instructions reflecting experience gained with an earlier scan. Since the DAT is a more compact representation of the film information than the film itself, it is efficient to store this tape for use in easy checkout of "afterthoughts" about the given experiment, or for a source of quick answers to questions arising in the planning of related future experiments.

Both phases of DAPR operate at Berkeley on the IBM 7094 II, under control of a specially written system executive program, TRIST (Ref. 3). A Flying Spot Digitizer (FSD) of the Hough-Powell type is attached on-line by means of a data channel dedicated to this use. This system of hardware has been in routine physics production for more than five years, measuring manually scanned events in the HAZE mode. A second FSD unit is now being built for tandem operation in conjunction with the existing unit. The computer configuration includes three data channels with sixteen tape drives, a disc storage module, and two 32, 768 word banks of core storage. The central processor of the model II computer has an effective speed nearly twice that of the 7094 model I, and this speed is required if tandem operation is to be limited by the digitizer and not by the computer.

The TRIST monitor program allows multiprogrammed operation of the computer, and sequences the several programs necessary to reduce each picture. TRIST is able to simultaneously control programs having three levels of priority in their demands on the central processing unit (CPU) of the computer. One high priority (A-level) program resides permanently in one of the core banks alongside TRIST itself. This program controls the FSD, performs the initial reduction of data from the film measurement, and then writes these intermediate results to the disc. When a sufficient quantity of data have accumulated on the disc, the executive program initiates a cycle of intermediate priority (B-level) processing, using the other core bank and all CPU time not needed by the A-level program. Several programs may be in the B-level cycle, and each inputs from disc, continues the processing, and then writes intermediate data requiring further processing to disc and final data to tape. Since the sum of A- and B-level processing requires less than the available CPU time, a still lower priority (C-level) program is brought into the second core bank to make use of the CPU time between B-level batches. This program operates on data unrelated to the immediate measurement process. Provision is made in both TRIST and the DAPR programs for operation with the tandem unit by using two B-level cycles of programs, one for each FSD unit.

Abstraction of Film Information to Tape

The first phase of DAPR, that which abstracts information from film to tape, operates at a speed determined by the FSD digitizing process. Since the same hardware is used, this part of DAPR operates at about the same rate as does HAZE. In film from the LRL 72" HBC, one normal and two orthogonal sweeps are required to cover the image completely in both modes. These measurement sweeps, together with the film move and stage retrace operations, take about 12 seconds per image, and thus imply a rate of 100 stereo triads per hour. Use of a tandem unit makes possible the measurement of two such triads in the same time period. The rate is of course dependent upon the image area to be covered, and smaller chambers go much faster. We shall here confine attention to the 72" HBC.

The A-level program (511) controls the FSD operation and associates digitizings from the FSD into track segments within each sweep. The relationship of this program to others of the DAPR abstraction phase is shown in Figure 1. Views are measured in the order of their appearance on the film, and provision is made for either Berkeley film format, with all views on one piece of film, or for that in which each view is on a different roll. Each view is measured by as many separate sweeps as are necessary to cover the entire area of the image in each of normal and orthogonal modes. The unit of data is the sweep; in each sweep the object is to recognize and follow all tracks properly oriented with respect to the sweep direction. Four consecutive digitizings on each track are averaged, and a set of these average points is chosen to represent the locus of the track. A selection algorithm is used which maintains a fairly uniform distribution of points along the track regardless of when in the sweep it ends. The number of intersections of the FSD spot with the track, and the number at which digitizings are found, are combined to obtain the fractional digitizing ratio. This ratio, which is guarded against double digitizings on one scan line, and against unusually long gaps, has been found in HAZE usage to be an excellent measure of relative ionization (Ref. 4).

Two modes of track following are used; one for beam tracks, and one for all others. Following of the beam tracks by a special procedure which introduces the knowledge of radius and direction obtained from the beam orbit is desirable because it greatly aids resolution of the difficulties frequently associated with this class: small angle crossings, small angle scatterings, close proximity to neighboring tracks. Tracks which do not fit beam orbits and those which are first detected after beam track initialization, are followed in the non-beam mode. Fiducials and other reference markings, and also such noise elements as coathangers and scratches are followed in this mode also, as though they were straight tracks.

Since this is the only reference to the film made by the DAPR system, the A-level program also makes quality checks of the data which it obtains, and if necessary initiates a new measurement of the sweep. Splices, fogged film, invalid format, overlapped frames, no beam tracks, too many beam tracks, are all conditions which may exist in this unscanned film. Their detection causes the program to print a warning statement. Hardware operation is monitored, and detected errors cause appropriate resets and warnings. If the real-time demands are not met, so that part of the digitizings are lost, a second sweep automatically is made at half speed. The program makes a reasonable number of attempts to achieve an acceptable measurement, and writes the results of valid sweeps or else the appropriate error records on the disc for further reduction.

When sufficient sweeps have been measured and their results have been stored on the disc, the executive program initiates a B-level cycle. Three programs are currently in the B-level cycle, since the number of instructions is such as to require so many core loads. A batch of data, consisting of the measurement results from 45 views, is processed by the first program in the B-level cycle, and then the second and third programs are called in turn to process the batch. One cycle takes place about every ten minutes for each FSD unit.

The first B-level program (512) gathers data from the several sweeps of each image, associates segments into tracks, recognizes fiducials, and excludes identifiable noise. Fiducials, followed as two track segments, are recognized and used to relate the raw FSD coordinates to a standard micron coordinate system common to all sweeps. Track-like noise in the central area of the image, often due to fiducials used by other systems, and to coathangers, is eliminated by comparison with a table of fixed noise segments common to most images. A surprisingly large number of other track segments, formed on the bubble usually visible in the 72" chamber, is eliminated as lying wholly outside the fiducial volume.

Data from the A-level program frequently have one track broken into several segments, often contained in more than one sweep. A track certification procedure is performed on segments as a condition for their being linked. Certification attempts to detect departures from polynomial fits of degree appropriate to the momentum, and either deletes an occasional point to make the segment "good", or else flags it as "bad". "Good" segments are linked, with the requirement that the result is "good". Where one track is represented in more than one sweep, the most appropriate measurement mode is selected.

The second B-level program (513) examines the track lists of all three stereo views of the bubble chamber, recognizes verticies, and matches tracks to produce a list of spatial verticies with their constituent tracks identified in the three views. These procedures, which we have developed during the last year, are described in more detail elsewhere (Ref. 5). Tracks are defined by their descriptive circles based upon end and middle points. Tracks in each view are examined for endpoint proximity. Pairs whose intersection is near the endpoint of at least one are provisionally associated into a view-vertex, and other nearby tracks are tested to see if their descriptive circles pass near this vertex point. When all possible view-verticies have been associated in each view, a spatial matching of these vertex points is made. Surviving sets are compared with the descriptive circles of all other tracks to pick up those tracks having a long gap in following near the vertex. This list of all tracks associated with the view-vertex in each stereo view is presented to the track match routine.

The result of the track match routine's operation is the production of a matrix in which each track in space is associated with its track-view images, and the assignment of parameters defining for the vertex the number of tracks and the uniqueness of their match. The vertex position in space together with the dip angle, azimuthal angle and radius in space for each matched track are also output. Unique matches are identified first, and then an attempt is made to work down ambiguities by means of logical procedures. This section, which we call "Generalized Track Cleanup", is of crucial importance and is the program area where most remaining changes will be made.

The parameters "Rank" and "Category" which describe number and uniqueness deserve special attention, because they are essential to the later scanning procedure. The track matching routine counts in each view the number of surviving tracks after matching to form the view's rank. Because of ambiguities and missing tracks, this rank may be different in each view. The middle of the three values representing three views is assigned as the rank of the space vertex. The track matching routine determines a category for each track in space. Tracks having a unique image in each of the three views are Category 1, while those with unique images in two views and no match in the third view are Category 2. Similarly, spatial tracks having an ambiguous pair of view-images in one or more views are Category 3 if all three views are present, and Category 4 if one view is missing. Categories 5 and 6 are used for spatial tracks which have three or more ambiguous view-images. The greatest track category in a vertex is assigned as the vertex category. Thus the highest quality verticies have Category 1, and the most confused verticies have Category 6. For example, an ideal 4-prong event produced from a charged beam particle would be Rank 5, Category 1.

The last program of the B-level cycle (514) reviews the achievements of the earlier programs for each triad, and produces a journal listing frames attempted, completed, rejected and skipped, and giving codes describing the problems encountered. This quality control is essential for providing assurance that the DAT is a true equivalent to the film information. Other programs run separately are also used to monitor the performance quality of the hardware (Ref. 6).

The DAT contains a set of records giving the fiducial coordinates, 18 precision points and bubble density information for each track in each view, and a table describing each vertex in the triad. Approximately 1000 triads of 72" data can be written on one reel of tape.

Usually all frames are abstracted to the DAT, but if the events are sparsely distributed in the film, it is possible to elect the option of prescanning. A control tape is input to the first program, listing the frames whose abstraction is desired. The resultant DAT contains only the selected frames. If the control tape also has event type and approximate vertex locations, it is possible to make an easy check for completeness in the later DAPR scanning process; however no special use of the prescanning information is made, except for frame selection.

Scanning the DAT for Selected Events

When abstraction has been completed for a section of film, the resultant DAT may be "scanned" by the DAPR scan program (Ref. 7). The relationship of this program to the subsequent geometry and kinematics program is shown in Figure 2. The scanning program uses scanning instructions of the same kind as those given to a manual scanner who would look visually at the film, but which are instead control cards for this automatic scan. Fiducial volume, beam track criteria, charge conservation rules, a description of the event types, and other criteria are given the program, as well as a procedure list of how to name and number the tracks of the selected events in order that they may conform to requirements of the following geometry and kinematics programs.

The scanning instructions are grouped by event type, and also by the rank and category of the verticies to which they are to be applied. Most verticies contain exactly the number of tracks needed to define the event, but occasionally there will be one or more additional ambiguous beam tracks associated with the vertex in one or more views. The DAPR scanner edits these events in accordance with its instructions; a common procedure selects as representing the beam those tracks which yield a spatial track most nearly agreeing with the standard beam orbit.

The programs of DAPR have been operational for several months, and have been used to gain experience which then leads to improvements in procedure. Most changes recently made have been in the area of track association and matching; the effect of these changes has been to sharpen the criteria for acceptance and exclusion of tracks in verticies. The process has grown considerably more sophisticated, and when we look back to early procedures they seem very naive. Scanning procedures have become more sophisticated also, just as usually occurs with manual scanning.

Early Operating Experience

A practice experiment was chosen early in the program development. This film is from a 6 Gev/c proton exposure in the 72" HBC, made in 1965 and measured in the HAZE system during 1966. The film format is easily handled by the FSD, and overall quality is good. On the other hand, the relatively high energy produces forward events, and the beam density and colimation are such as to produce a substantial number of overlaid beam tracks. Confusion from coathangers and extraneous tracks is "typically bad". In the HAZE processing, manual scanning was done for all except 2-prong events in about 180 rolls of film; thus an adequate base exists for comparison of DAPR with HAZE results.

Much of our development of DAPR in its present form resulted from a careful study of forty consecutive 4-prong events in this practice film. Later studies used eighty events. Events were measured and their results analysed to determine necessary improvements in the logical procedures of track association. These changes were incorporated into the programs, and the whole process was repeated.

It is important to have good diagnostic procedures in the development of pattern recognition programs. Two levels of diagnostic graphics have been important: one, relating the digitizings to the followed tracks, and another, mapping the tracks of an entire view in their final linked form. Once track following had been perfected to a reasonable degree, we found the track map to be invaluable. Tracks are mentioned by name in the printed program diagnostics, and can then be identified on the map in such a way that we can easily review the decisions of the recognition process.

The present procedures are clearly more stringent than are needed, and result in the exclusion of tracks really participating in some events, due to their marginal failures to meet tight tolerances. The eighty event study, which was completed in September 1968, had about two-thirds of the events processed in such a way as to give good geometry input, and approximately one-third which were found as verticies, but in which either one track was ruled out, or else unresolved ambiguities prevented a unique selection of tracks from being output. The most frequent ambiguity was caused by beam tracks not related to the event, but passing within a few microns of the vertex on film. The philosophy has been to output clean events and leave the others, but we are finding it desirable to improve the procedures which clean up these partially obscured events. A stepped beam which has few such overlaid beam tracks would materially improve the DAPR throughput.

Some representative events are shown in Figures 3 through 8. In these displays, the actual bubble chamber photograph is reproduced on the left, the display of the tracks in their final form corresponding to the DAT representation is in the center, and the selected event is shown on the right side of the figure. View two of the stereo triad is shown in all displays. In general it will be noticed that the tracks are followed faithfully, and over all of their unobscured length. An 8-prong event is shown in Figure 9 primarily to demonstrate that DAPR can really produce such an event. In each case the event has been reconstructed by the FOG-CLOUDY geometry and kinematics programs, and the results compared with those from the HAZE measurement. Excellent agreement of parameters and of the departue of measured points from three view orbits was found in these comparisons. One interesting deviation of the HAZE scanners from their instructions about roadmaking was consistently noticed: they often truncated the tracks severely, thus impairing measurement quality. A typical comparison of HAZE roads with DAPR tracks is shown in Figure 10. More detailed comparisons of greater numbers of events will be made when a program for making such comparisons has been completed.

The results of the eighty event study were gratifying even though they indicated the need of further logical elements in the program areas of generalized track cleanup. In these pictures, we found only two fake events, both of which corresponded to the spatial coincidence of a real vertex with some other object in the chamber. One non-beam two-prong event was closely passed by a beam track, forming an apparent four-prong event. One two-prong event with a short V^0 decay was found as a four-prong event. Neither of these cases was regarded as serious, since the imposition of a simple scanning criterion can eliminate the former, and testing of Q-value can indicate the latter.

Some of the spatial coincidences which can simulate 4-prong events are shown in Figure 11. Most can be eliminated by requiring that followed tracks, which are partitioned into two tracks at a vertex, be "bad" tracks according to track certification. The underlying assumption is that those tracks which really participate in verticies undergo some change in direction or momentum at the vertex.

Recent Experience with a Five Roll Sample Experiment

In October 1968, it was decided to operate DAPR on a five roll sample of data, both to test its performance on a larger variety of event configurations, and also to learn how to operate it in moderate volume. Five contiguous rolls were chosen from the practice experiment, and all frames were abstracted in a single pass, interrupted only by other uses of the computer and by a few program malfunctions requiring restarts at the next unmeasured frame. There were 3218 frames in these five rolls. The longest single run abstracted 361 frames.

There has only been time to compare the results of the DAPR scan with the previous HAZE scan for 4-prong events in these rolls. The DAPR scanning program was caused to produce a list of all 4-prong events which meet the scanning criteria, and also a list of all additional verticies by rank and category. Each 4-prong event reported by either the HAZE scanner or the DAPR scan program was tabulated by frame and location.

There were 1030 such entries, of which 215 were reported by the DAPR scanner but not the HAZE scanner. Each of these events was carefully inspected on a scanning table, and a decision was made as to whether the event was valid or invalid within the criteria of the original HAZE scanning instructions. A somewhat surprising number of 113 was found to be valid; these were added to the 815 events found by the HAZE scanner, to form a master list of valid 4-prong events totaling 928.

The distribution of the 928 valid 4-prong events is shown in Table 1 for both DAPR and HAZE scans. The throughput value observed in the eighty event study is also observed here: about two-thirds of the events in frames on the DAT are in a form suitable for output to the geometry program; about one-third do not meet present criteria for selection.

TABLE 1: DISTRIBUTION OF 928 4-PRONG EVENTS FOUND BY EITHER DAPR OR HAZE SCANNER IN FIVE ROLL STUDY

Results from DAPR Scan	
Events output to geometry program	534
Events not meeting present criteria	254
Events in frames not on DAT	140
Results from HAZE Scan	
Events output to geometry program	713
Events not satisfactorily measured	102
Events missing in manual scan	113

The distribution of 102 verticies which meet the DAPR scanning criteria for 4-prong events but which are not valid is shown in Table 2. Most of these are of the previously discussed type of spatial coincidences. Non-beam events resulted when the HAZE scanners unconsciously tightened the angular acceptance criteria over the instructions given both them and DAPR. Some entries are from 6- and 8-prong events with two or four constituent tracks deleted, so as to produce invalid 4-prong events. These will most likely be cured by the improved version of "generalized track cleanup" previously discussed. The seven events labeled "fake" fall into two classes, both of which are distinguishable from valid events by appropriate scanning criteria. One group of fakes was composed of either the coincident crossing of several beam tracks, or else two beam tracks and a dense electron spiral. The remaining three fakes were caused by the spatial coincidence of three unrelated tracks.

TABLE 2: DISTRIBUTION OF 102 EVENTS FOUND BY DAPR BUT NOT HAZE SCANNER NOT MEETING VISUAL 4-PRONG CRITERIA

2-Prong + Interloper	45
4-Prong Non-Beam Events	27
2-Prong + Short V^o	8
6-Prong with two tracks deleted	8
Fake Events	7
Beam Track + n-star 3-Prong	3
4-Prong with short secondary	2
2-Prong with short secondary	1
8-Prong with four tracks deleted	1

It is of some interest to examine the rank and category descriptors of the 534 valid 4-prong events output by DAPR to the geometry program. It will be recalled that an ideal 4-prong event is rank 5, category 1; this represents a vertex formed by exactly five spatial tracks, each of which is the uniquely matched result of one track in each view. The DAPR scanning program was conditioned to eliminate as many beam track ambiguities as possible, and to appropriately modify the rank and category descriptors associated with the reduced vertex. Events having reduced values of R5C1, R5C2, or R4C2 were then subjected to beam track, fiducial volume and charge conservation tests. Table 3 shows the distribution of rank and category of the 534 events output to the geometry program. It is apparent that while most of the events are from clean, completely followed track sets, about twenty percent have one or more extra beam tracks passing within the resolution limit of their verticies.

TABLE 3: DISTRIBUTION BY RANK AND CATEGORY OF 534 4-PRONG EVENTS OUTPUT BY DAPR SCANNER

Category	1	2	3	5
Rank				
4		1		
5	323	76	29	
6	12	39	38	6
7		2	7	1

Similarly, it is of interest to examine the rank and category of the 254 valid 4-prong events not output by DAPR to the geometry program. The distribution of these events is shown in Table 4. The most abundant class, one-third of the total, is that composed of R4C1 and R4C2 events in which one track was deleted in the matching process. Another third of the events is included here due to the presence of one or more extra tracks not resolved by the current version of "generalized track cleanup". Both classes will be significantly improved by the previously discussed changes to "generalized track cleanup". The 34 events grouped under the heading "no vertex" are mostly due to a program bug which allows verticies to be lost in the track matching process under certain conditions. It is of course possible for a few events to have been missed due to the failure of the vertex finding algorithm.

TABLE 4: DISTRIBUTION BY RANK AND CATEGORY OF 254 4-PRONG EVENTS NOT MEETING DAPR SELECTION CRITERIA

Category	1	2	3	4	5	6
Rank						
No vertex	34					
2	1	1				
3	9	6	1			
4	63	19	6	1		
5	4	6	21	5	5	4
6	22	5	10	2	3	1
7	5	2	6	3	2	
8		2	2		1	
9			1			
10	1					

Conclusion

We conclude from this five roll study that DAPR is on rather firm ground in recognizing events. The addition of a few more knowledgeable event criteria will eliminate almost all invalid events. The improvement to the level of sophistication of the "generalized track cleanup" logic should eliminate most of the remaining invalid events, and should allow the output of most valid 4-prong events now not output. The 140 events which were in frames not contained on the DAT were mostly lost due to false error signals caused by inappropriate tolerances; these in turn were due to our lack of operating experience. It is not unreasonable to expect that a relatively few modifications in the areas mentioned will achieve output of 80% of the events in the film, with less than 1% fakes. Not counted as fakes are 2-prong events with close V^0 decays, since very short V^0's occur in manually scanned events as well, and must be guarded against by means of kinematics.

Another result of the five roll study is the confirmation of predictions concerning speed of operation. An extensive and time consuming set of diagnostics was obtained during the abstraction of these rolls in order to be able to review the failures and omissions. Correction of the observed operating times by amounts appropriate to these diagnostics brings the measurement rate from the observed value of 65 up to a corrected value of 95 triads per hour, a rate in excellent agreement with the expected value. The scanning program searched these DAT tapes at rates of about 7200 triads per hour; elimination of remaining fixed noise tracks will reduce the volume of data on this tape by about one third, and therefore will allow scanning at the expected rate of 10,000 triads per hour.

We have deferred consideration of 2-prong events, especially in the 72" HBC, because the vertex algorithm must be augmented to find small angle scatters. The track following program cannot be depended on to separately follow two tracks whose scattering angle is small. Such 2-prong events then consist of a "beam track" which is in reality a follow-thru of the beam and scattered track, and the recoil. There is only one track end near the vertex, that of the recoil, and so the vertex algorithm fails. We are saved if the beam track follow-thru is certified as "bad" because of its scatter at the vertex. Few enough "bad" beam tracks are found that it is feasible to compare all apparent recoils with the partitioned "bad" beam tracks, especially when the remaining fixed noise has been eliminated.

We believe that achievement of 80% throughput in the practice experiment is a suitable point to begin physics production. The experiment was intentionally chosen to be a difficult one. A cleaner chamber with fewer coathangers which simulate tracks, with fewer overlapping beam tracks, and perhaps with lower beam momentum would do very much better. Improved procedures will be based upon continued experience.

We have emphasized the fully automatic mode of operation for DAPR, for we believe that is where the future lies. We would expect, however, that manual vertex scanning will be used while the experimenters gain confidence in DAPR's ability, and whenever events are sparse. It is likely that most film from large chambers will be entirely abstracted, rather than depend on manual frame selection.

We envision a gradual progression of decreased dependence on the film once the abstraction has been made, until eventually the film is used only to convey information from the chamber to the DAT. The stage will then be set for direct production of a DAT without film intermediary. This era would then allow for bubble chambers the same advantages of immediate, online data analysis which have been so useful in many spark chamber experiments, while preserving the precision and resolution of the bubble chamber as a detector. Only a fully automatic system like DAPR can go online in this manner; we believe such a system will produce significant benefits to bubble chamber physics.

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Figure Captions

Figure 1. Organization of the film abstraction phase.

2. Organization of the scanning phase.

3. A typical four-prong event is shown as it appears (a) on the film, (b) in the presence of all tracks abstracted from the film image, and (c) as selected and identified by the scanning program. Note that the forward positive track is obscured by an overlaid beam track for part of its length, but is initialized and followed after it separates from this track. The track is associated with the vertex by means of the exhaustive search performed after initial location of the vertex point.

4. This four-prong event has typically forward tracks. Initialization occurs as soon as the tracks separate.

5. The "interloper track" forms fake vertices with some of the outgoing tracks, but the four-prong is selected without confusion.

6. This event was not selected. Although the abstraction of this view was complete, the necessary view 1 had its short track to the secondary entirely obscured by the overlaying positive track. This condition is beyond the present program's ability and produced a R4Cl vertex that was not output to the geometry program.

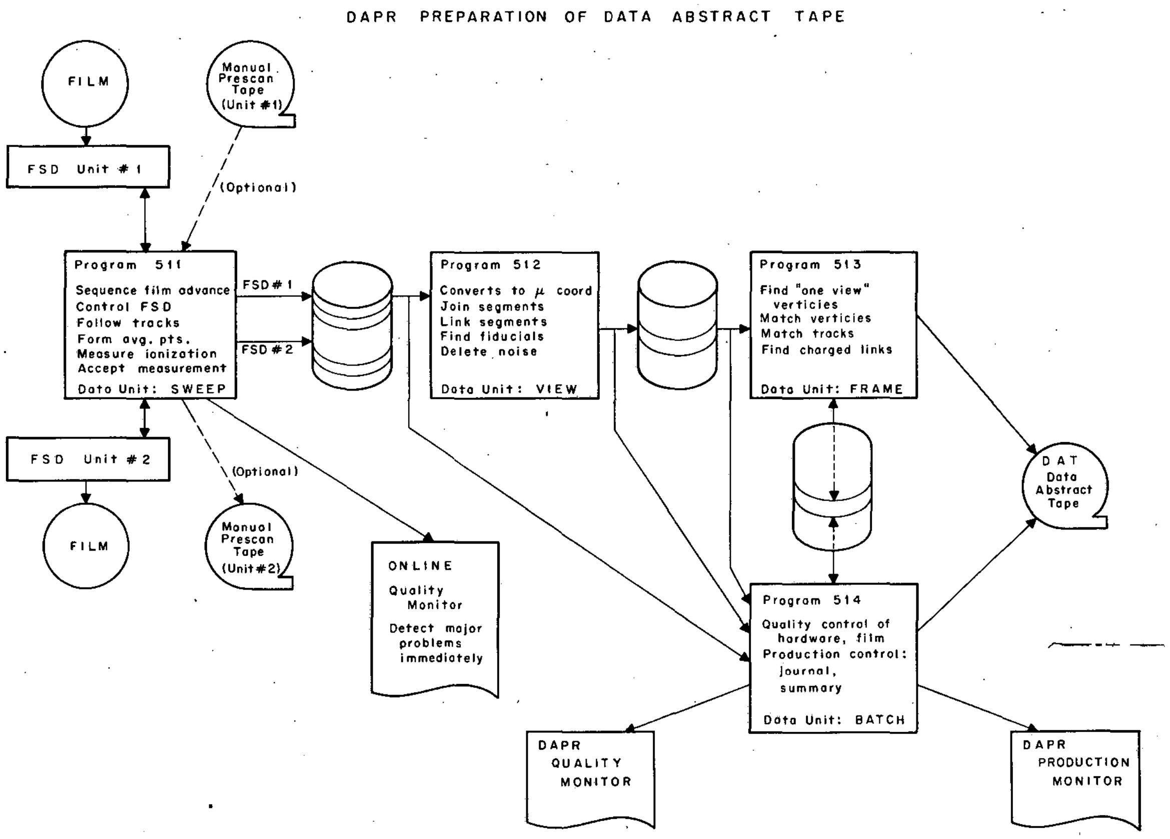
7. Two four-prong events in one frame. The short track in one of them is 2.2 cm long in chamber space.

8. This four-prong event is shown to give some idea of the ability of track-matching procedures to unambiguously resolve tracks of similar angle and momentum. Notice that the second positive track crosses a dense region of beam tracks and that no average points are taken in this region.

9. An eight-prong event can also be processed. Again note the ability of track match to unambiguously associate tracks of similar angle and momentum.

Figure 10. A comparison of (a) the roads made by the HAZE scanner with (b) the DAPR track output. Note that track identification assigned by DAPR agrees with that manually assigned by the HAZE scanner.

11. Some vertex coincidences can simulate four-prong events. A procedure is described in the text by which interloper tracks can be easily excluded.



XBL675-3139

Fig. 1

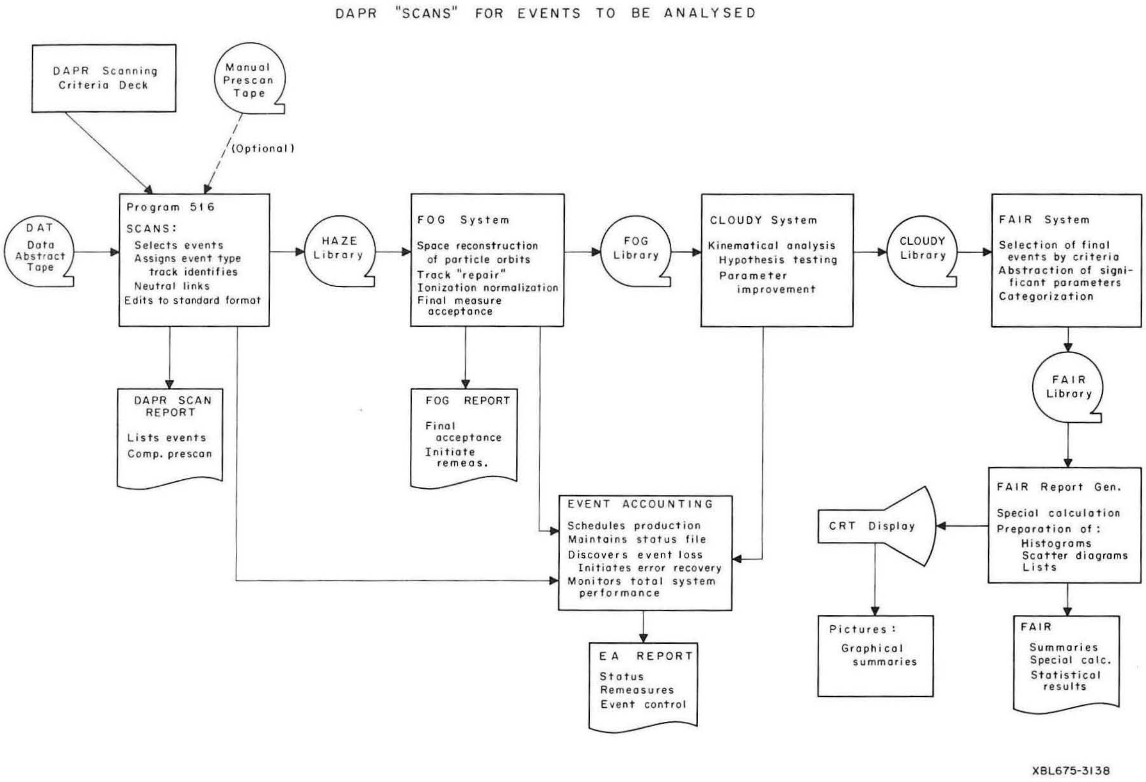
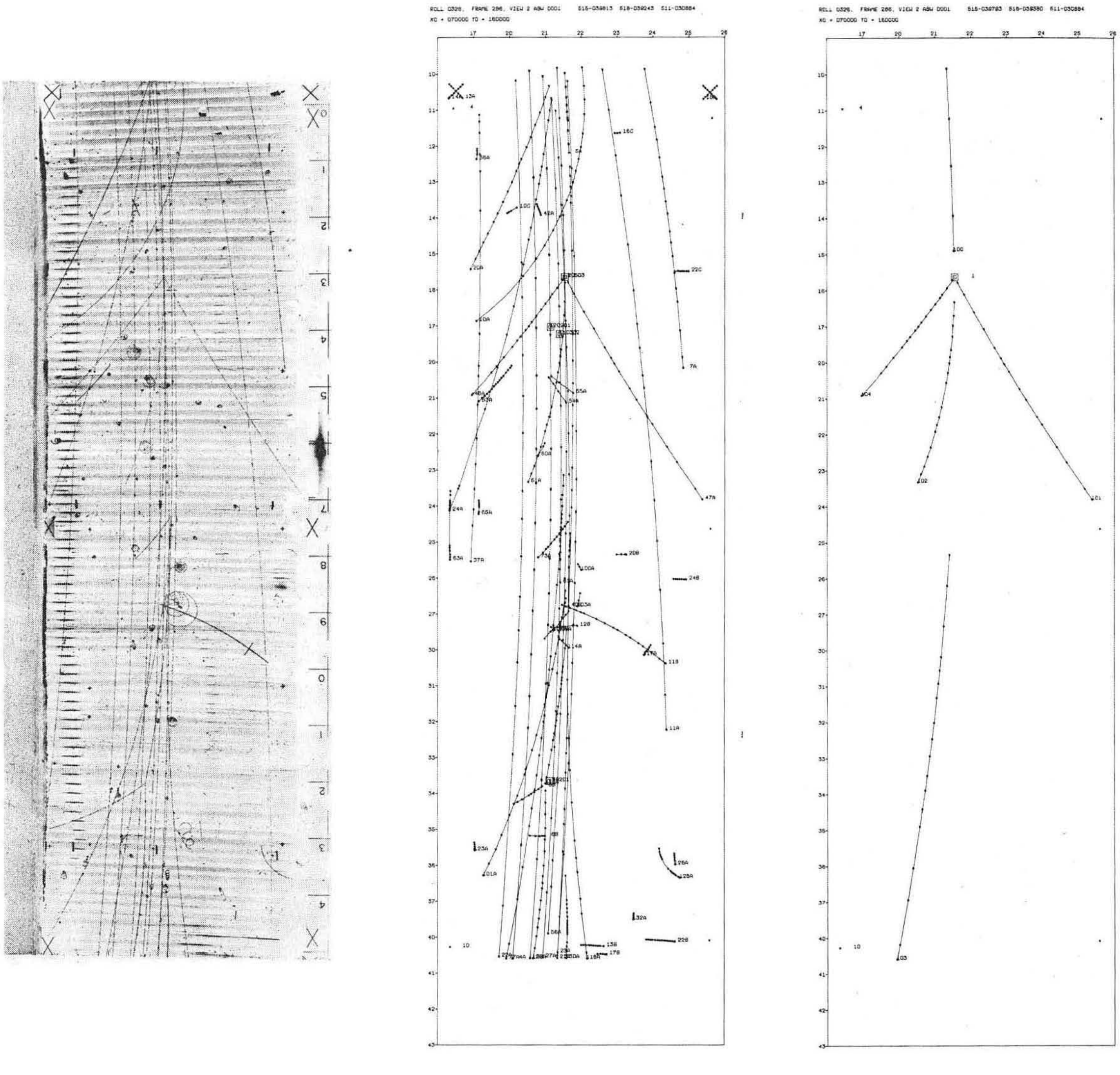
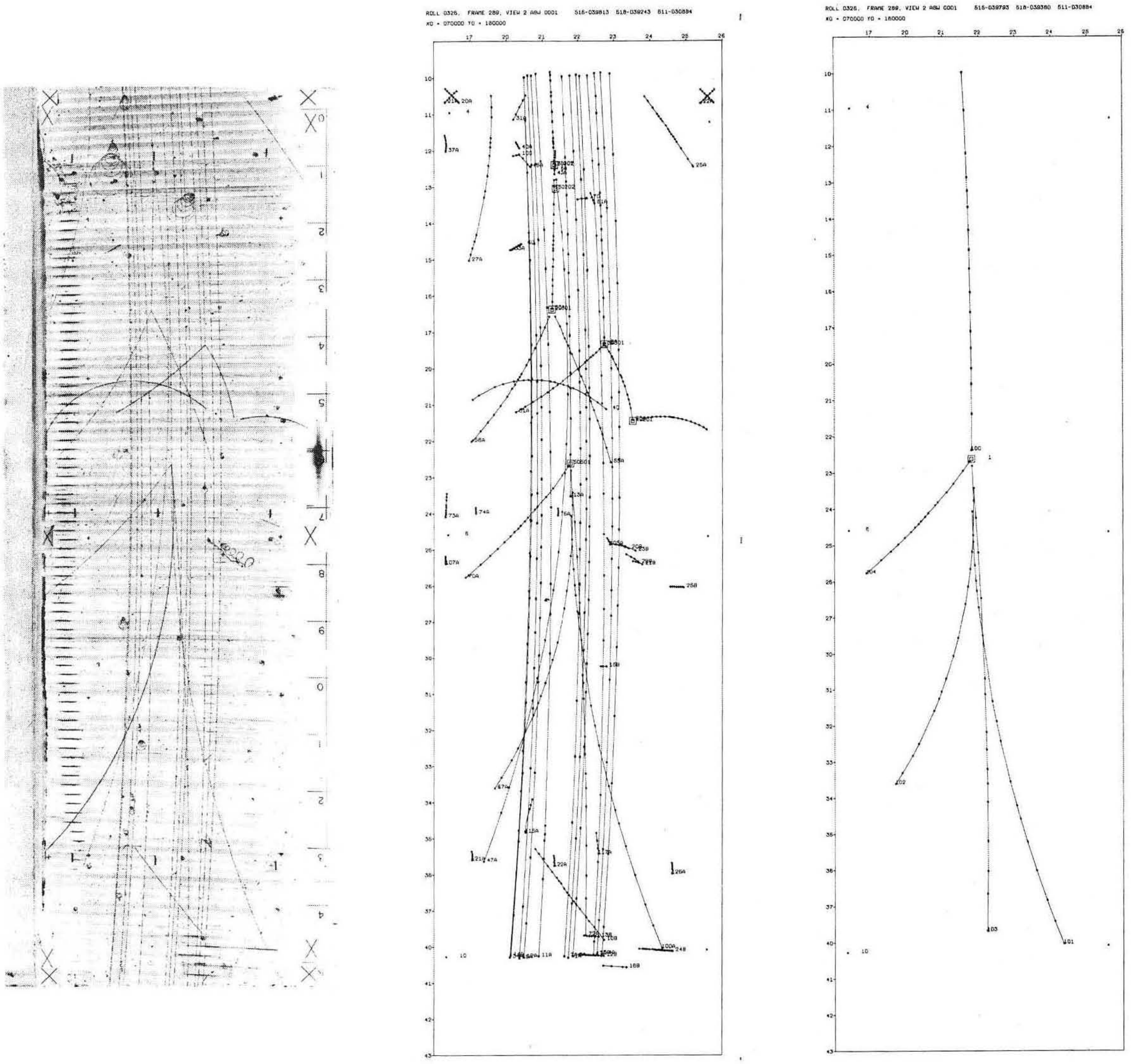

DAPR "SCANS" FOR EVENTS TO BE ANALYSED
DAPR Scanning Criteria Deck
Manual Prescan Tape
(Optional)
DAT Data Abstract Tape
Program 516
SCANS:
Selects events
Assigns event type
track identifies
Neutral links
Edits to standard format
HAZE Library
FOG System
Space reconstruction of particle orbits
Track "repair"
Ionization normalization
Final measure acceptance
FOG Library
CLOUDY System
Kinematical analysis
Hypothesis testing
Parameter improvement
CLOUDY Library
FAIR System
Selection of final events by criteria
Abstraction of significant parameters
Categorization
DAPR SCAN REPORT
Lists events
Comp. prescan
FOG REPORT
Final acceptance
Initiate remeas.
FAIR Library
EVENT ACCOUNTING
Schedules production
Maintains status file
Discovers event loss
Initiates error recovery
Monitors total system performance
FAIR Report Gen.
Special calculation
Preparation of:
Histograms
Scatter diagrams
Lists
CRT Display
Pictures:
Graphical summaries
FAIR
Summaries
Special calc.
Statistical results
EA REPORT
Status
Remeasures
Event control
XBL675-3138

Fig. 2



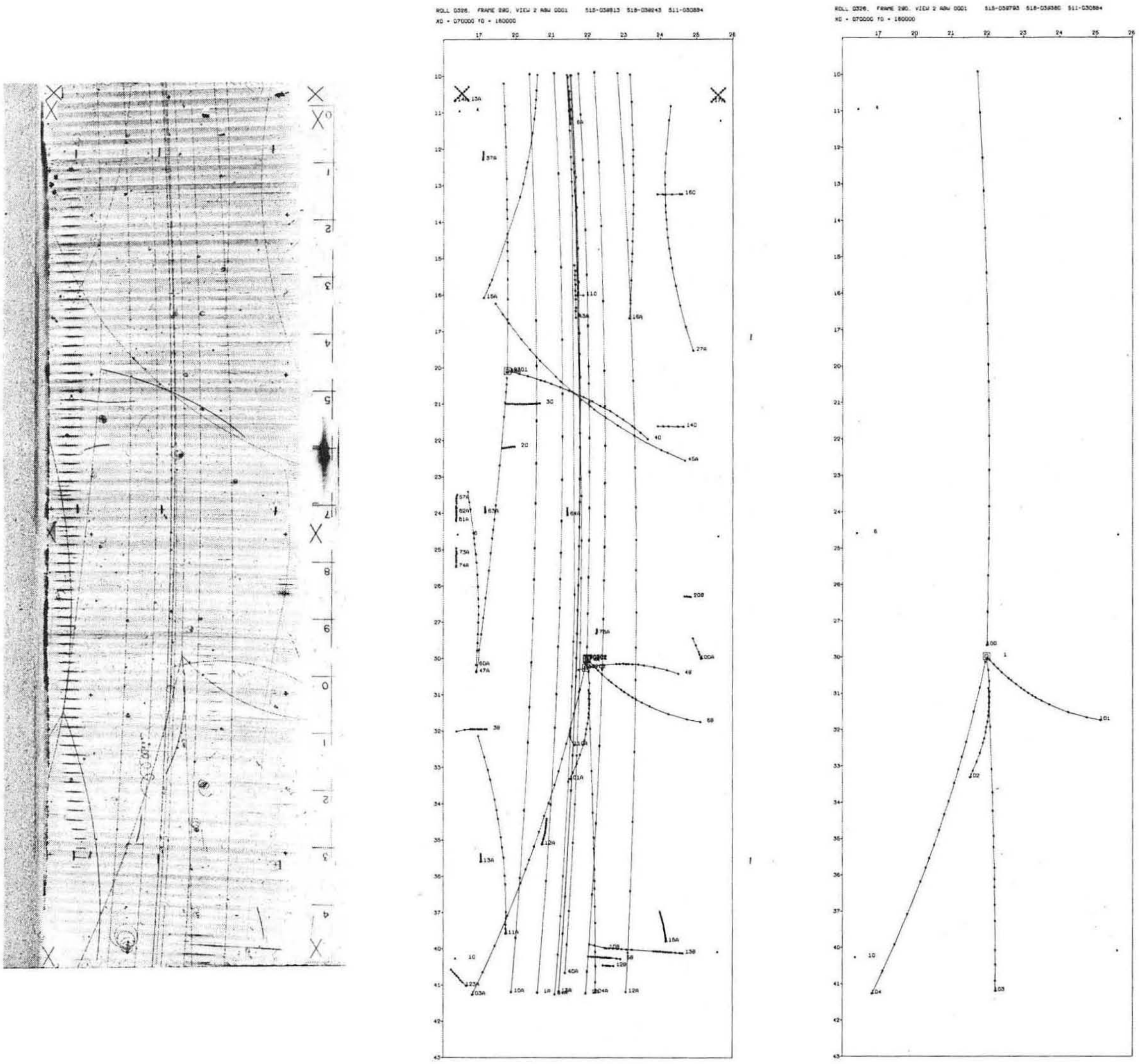
XBB 6810-6037

Fig. 3



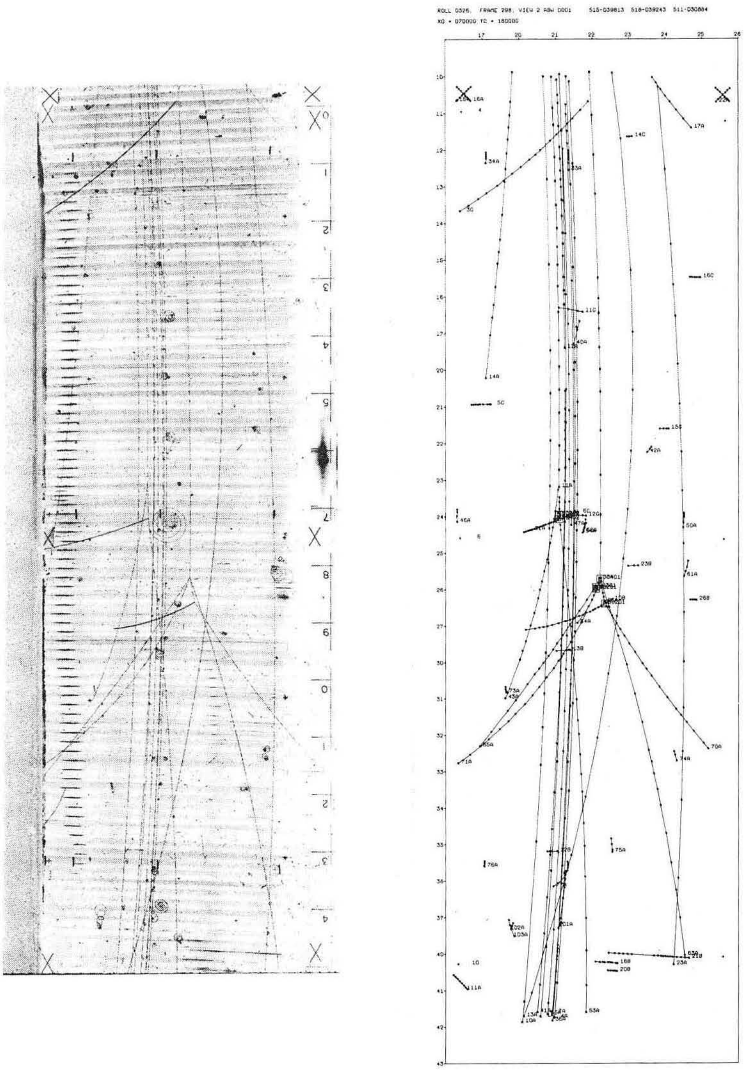
XBB 6810-6052

Fig. 4



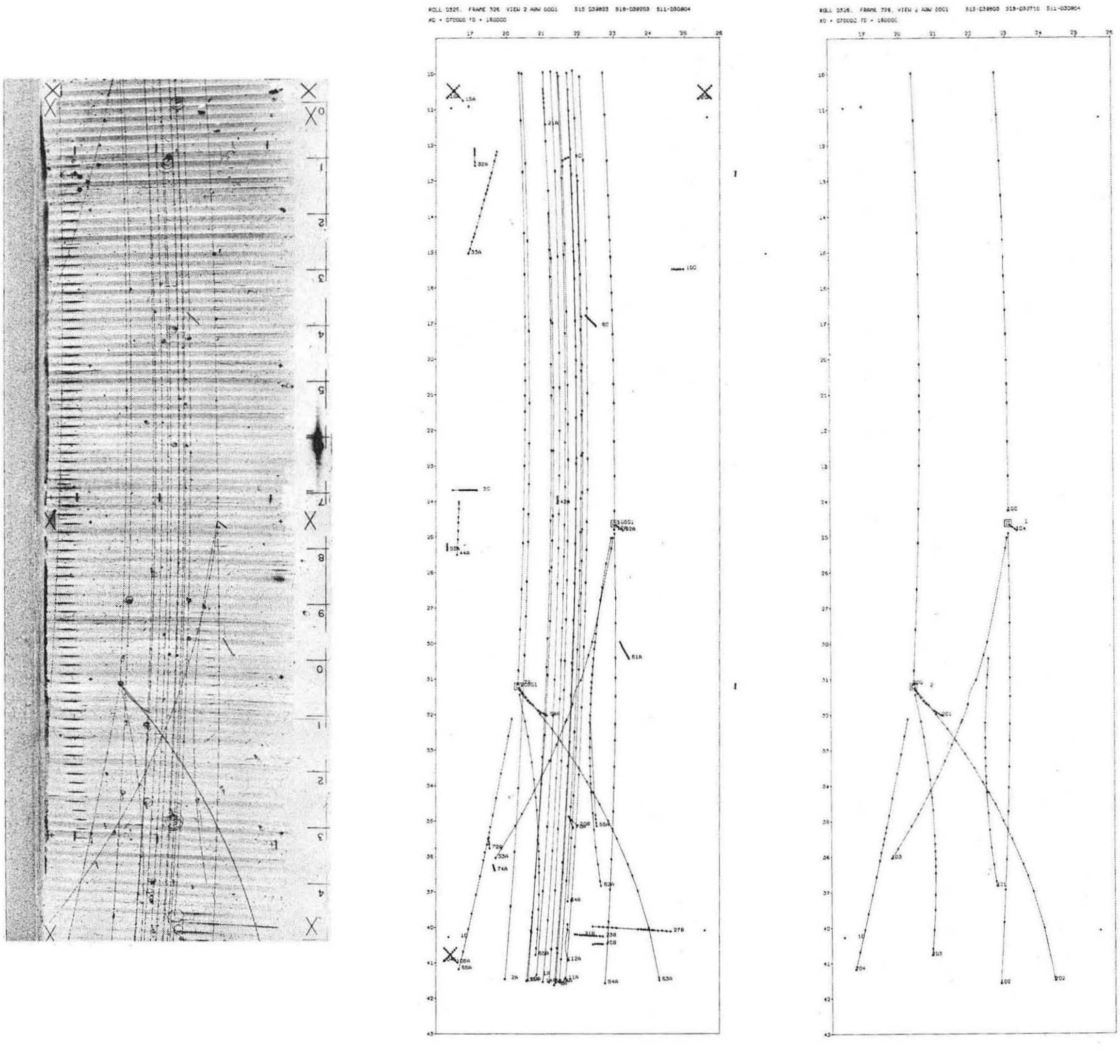
XBB 6810-6050

Fig. 5



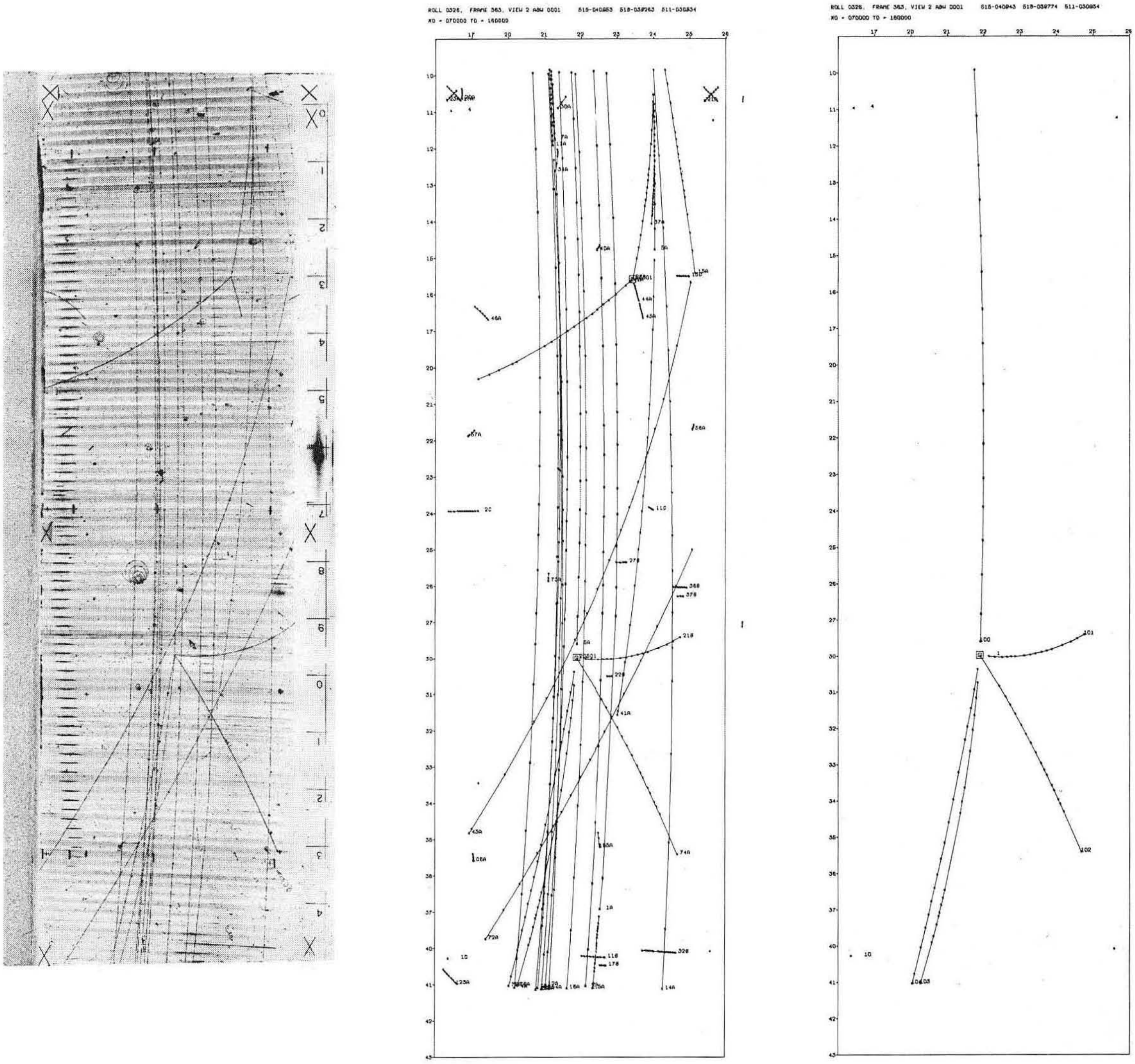
XBB 6810-6036

Fig. 6



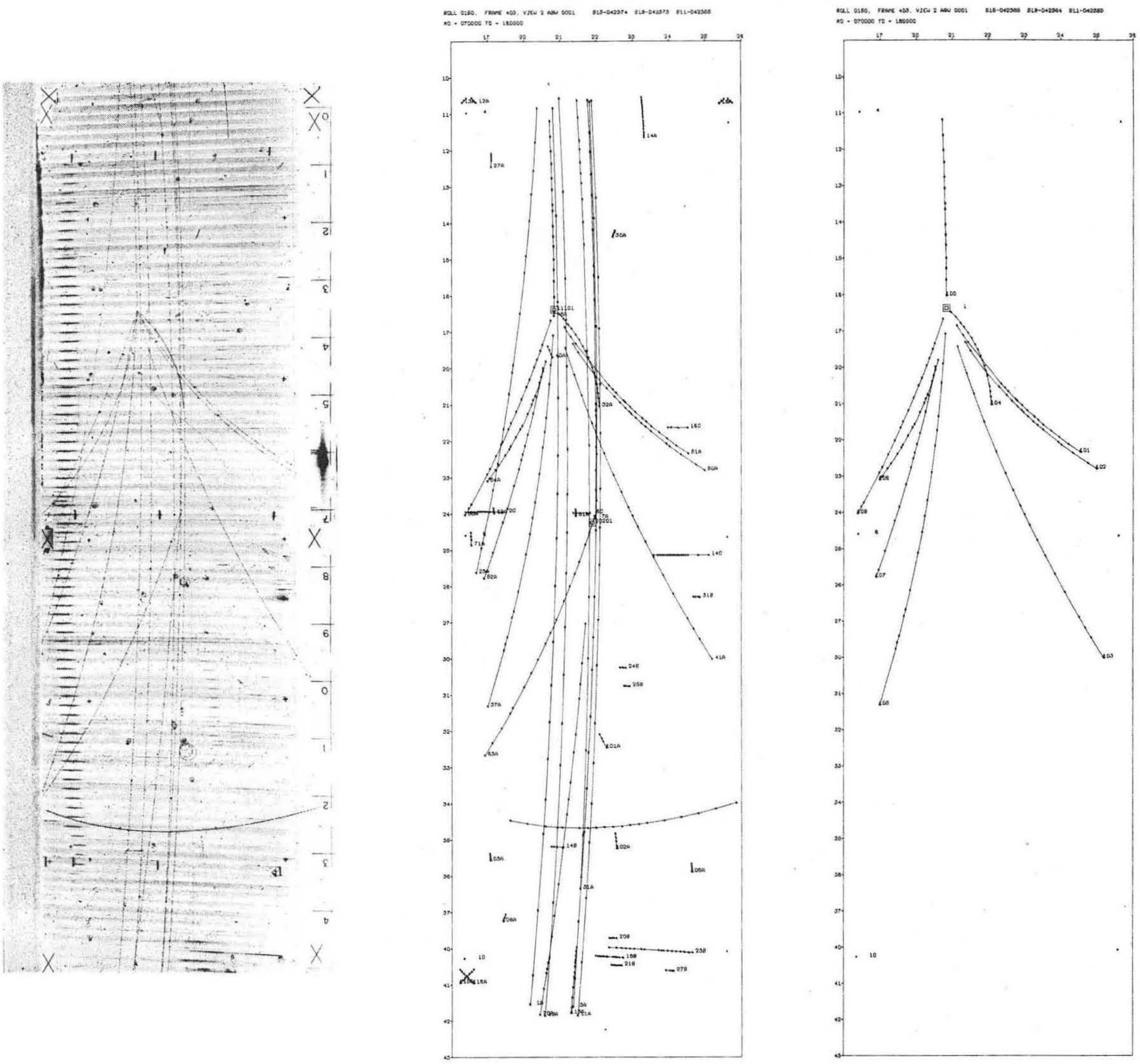
XBB 6810-6047

Fig. 7



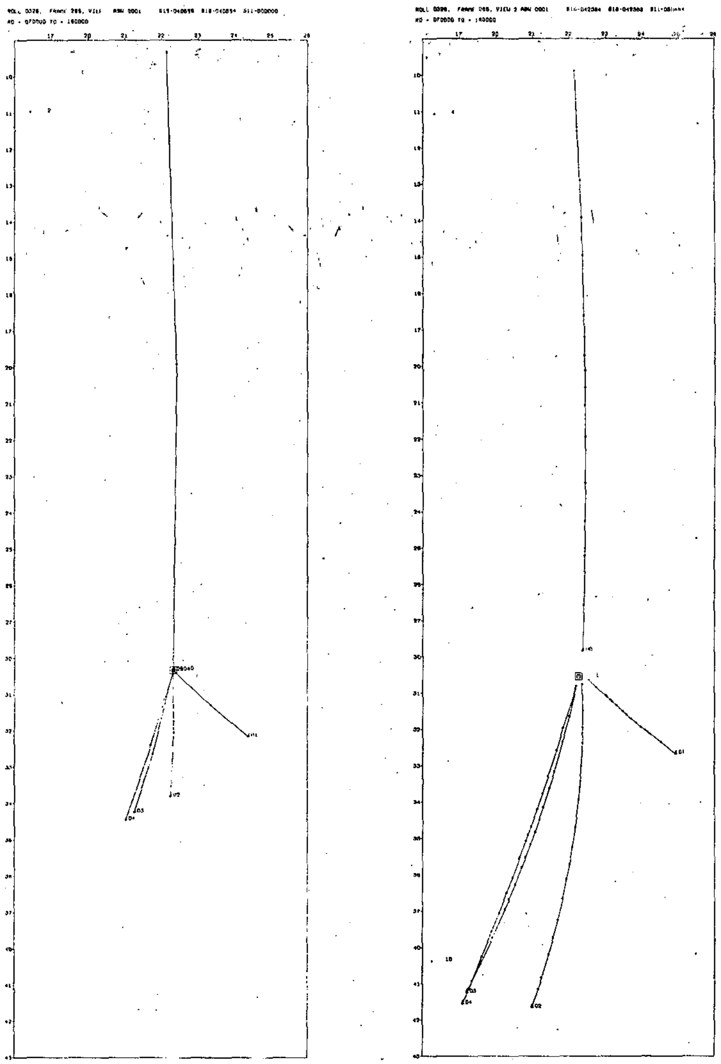
XBB 6810-6042

Fig. 8



XBB 6810-6155

Fig. 9



XBB 6810-6154

Fig. 10

Vertex Coincidences Simulating 4-Prong Events

BT 2-Prong + NBT Interloper NBT 2-Prong + BT Interloper

n-star 3-Prong + BT Interloper 2-Prong + Short V°

XBL 6810-6047

Fig. 11

TECHNICAL INFORMATION DIVISION
LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720