PROGRAM DEVELOPMENTS IN THE CERN F3D SPARK SYSTEM

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ABSTRACT

This paper describes the current program developments at CERN for the automatic analysis of a second spark chamber experiment using the HPD flying spot digitizer.

1. THE EXPERIMENT

1.1 Description of the experimental arrangement

A preliminary report on the experiment has been presented at the International Conference on High-Energy Physics (Dubna 1964) by P. Astbury et al. Figure 1 shows a schematic diagram of the experimental arrangement.

A high-energy negative beam from the CERN PS traverses a beam telescope with beam defining counters. Two threshold Cerenkov counters are used to separate $\pi^-$, $K^-$ and $\bar{p}$ in the beam. Four small spark chambers and a bending magnet define the path and the momentum of the incident particle. The hydrogen target is surrounded by a lead scintillator sandwich anti-coincidence counter. The secondaries are detected in a large magnet spark chamber which has a useful volume of $60 \times 67 \times 170 \text{ cm}^3$ in a field of 10.7 kG and which contains 72 gaps.

Figure 2 shows a schematic drawing of the magnet, the magnetic spark chamber and the optical system. Two stereo views of the spark chamber are taken with two lenses on 70 mm unperforated film. The stereo
angle is 12° 30′; the demagnification factor at beam level is about 26.

Reactions of the following types are being studied:

(1) $K^- + p \rightarrow K^0 + n$ at 9.5 GeV/c

(2) $\pi^- + p \rightarrow K^0 + K^0 + n$ at 9.5 GeV/c

Figure 3 shows two $K^0$ meson decays from the reaction of the second type. About 800 events of this type have been photographed in February 1964 together with 500 events of type 1. They have been measured on IEP equipment and have been analysed by the REAP - THRESH - GRIND chain of programs.

The preliminary results indicate that the system is satisfactory. So, it is planned to take a large number of pictures starting in December 1964. Justifications for automatic measurement with the HPD are the desire for a greater accuracy and the pressing need for a shorter analysis time. It takes at present about 40 minutes to measure an event by hand and 30% of the measurements have to be repeated.

1.2 The frame format

Figure 4 shows another double neutral event and a typical frame format. The length of the frame is 130 mm. On the left hand side a set of lights indicate the picture number and the triggering mode in a binary code for automatic recognition. The image of the large magnetic spark chamber surrounded by fiducial crosses occupies the central part of the frame. It consists actually of six chambers each containing twelve 8 mm gaps separated by 12 mm thick plates. On the right hand side are placed the two 90° stereoscopic views of the four beam chambers. Since the HPD is not yet equipped with a 70 mm film transport, each roll has been divided down the middle into two 35 mm films, each containing one view. Because each view contains all the necessary features such as Brenner marks and data box, there is no difficulty in analysing each such 35 mm film strip separately.
2. **THE ANALYSIS OF THE DATA**

2.1 **Pre-scanning**

Due to the small events-to-pictures ratio (about 1/15, 1/40 for events of type 1, 2 respectively) and the relatively large HPD measuring time (approximately 40 sec for the 2 views), pre-scanning is economic for this experiment (average time taken is 10 sec per picture).

The only information needed by the computer is the number of the picture containing a good event. Further desirable information may easily be provided, such as the type of the event (one or two neutral V's), the number of the gap where an apex appears to be and the number of background beam tracks traversing the magnetic chamber.

2.2 **The automatic measurement**

The computer reads from magnetic tape the scanning information for each event to be analysed and instructs the HPD to advance to the appropriate frame. Measurement is then started and the frame number immediately recognised to make sure that the correct picture is being processed. In order for the flying spot to cross a spark at least three times, a scan line separation of 90 microns has been chosen for this experiment. A circular buffer, at present of 14,000 words, is set up in the IBM 7090 memory to receive the digitings from the on-line HPD. (About 15 - 20,000 per view.) Data reduction is performed simultaneously with the measurement. The program continuously checks that the data are not overwitten before processing occurs.

2.3 **Data reduction**

Fiducials and sparks are found, while measurement is taking place, by the subroutines already used for the analysis of the previous experiment\(^2,\ 3\). A slight improvement was made to the spark finding routine in order to reduce the background due to scratches and other objects on the film. In fact, as suggested by the geometry of this chamber, a sufficiently long object can be distinguished from a spark by its presence also in the thick plate region.
The reconstruction of the linear tracks in the beam chambers is performed by the existing routines described in references 2 and 3.

2.4 Pattern recognition in the magnet spark chamber

Association of sparks into tracks and recognition of neutral V's occurs while the HPD advances the film to the next event.

First of all, displacement of sparks from tracks due to magnetic and electric fields are removed or, at least, minimised by applying systematic corrections to the co-ordinates of the spark images. In particular, the magnetic field staggering is removed by adding or subtracting an average staggering correction term to the spark co-ordinate (parallel to the plates). The electric field staggering is reduced by displacing the other co-ordinate (x), nearer to the cathode.

The sparks found in the chamber image are scanned backwards (from gap 72 to gap 1) by the track following program. At each gap, every spark is either assigned to a previously established track or to a new "starting-trial". The threshold for an established track is at present fixed at 4 sparks.

Coarse predictions from linear extrapolations are used in the initialisation stage. More accurate predictions from a parabolic least squares fit are used for the track following. Due to the regularity of the x-co-ordinates, each prediction is calculated as a simple linear combination of the x-co-ordinates of the sparks found in the 'n' preceding gaps. Missing sparks are replaced by their corresponding predictions. Errors due to residual staggerings are minimised by using an even number for 'n'. A maximum of n = 6 is used and it has proved to be quite adequate. Whenever a very precise prediction is needed, for instance when two or more tracks are crossing or when two tracks are approaching an apex or when a track has several consecutive missing sparks, then an ellipse is fitted to all the sparks of the known portion of the track.

In fact, due to the optics of the experiment, the track images in the magnet spark chamber are best approximated by ellipses. The ratio,
R, between the major and minor axes, and the axis orientation of the ellipse are known with sufficient accuracy. Such an ellipse may be represented by an equation of the type:

\[ ax^2 + by^2 + cz + d = 0 \]

The three parameters \( a, b, c \) are determined by forcing the curve through three given points on the track. These are chosen as widely separated as possible on the parabolic segment which best fits in the least squares sense all the sparks previously associated with the track.

Since all the tracks in a view are followed simultaneously, information on their relative behaviour is instantaneously available to the program, which can therefore anticipate the track crossing regions and the apices and can then decide the suitable prediction mode. The uncertainties associated with each kind of prediction have been determined experimentally and have been used to define the acceptance regions for sparks in succeeding gaps.

Apices are recognised in the gaps indicated by the scanner wherever two tracks having curvatures of opposite signs are closer than a preset maximum separation. Solution of ambiguities, if any, is postponed to the end of the track-following (gap 1). For ambiguities which cannot be solved at this level of the program the decision is left to THRESH or GRIND which will be used for the geometrical reconstruction and the kinematical analysis of the events, respectively.

Figure 5 shows one ambiguous case which cannot be resolved at this level of the program.

2.5 Correlation of the two views

The part of the program which deals with this is not yet tested. Correlation of neutral V's is based on the comparison of apex positions. Ambiguities are solved by matching spark patterns. The arms of the V's are correlated by comparing the signs of the curvatures.
2.6 How to handle the rejections

Although it is expected that a reasonably good efficiency will be achieved with the system, no doubt there will be a small percentage of non-recognised events.

The idea is to avoid measuring these pictures on IEP's and to make use instead of the HPD measurements available in the computer memory. To this end a set of subroutines is being written which will store the spark array of the rejected events on magnetic tape and will provide an off-line plot, on a Calcomp plotter, of the recognised tracks. (It takes about 5 min/plot.) Looking at such plots and knowing the reason for rejecting the event, one can provide the program with supplementary information to obtain the correct recognition. Doing so, re-measurements are avoided and off-line reprocessing should bring in a good fraction of the lost events.

3. PRELIMINARY RESULTS

3.1 Experience with the system

The main differences between this and the previous spark chamber experiment analysed on the HPD are:

1) The number of digitizings is increased by a factor of 3 - 4.
2) Tracks are non-linear and are complicated by magnetic and electric field staggerings.
3) Events are more complex.
4) Films are pre-scanned.

Problems arising from the first three points seem to have been satisfactorily solved, but human intervention at point 4) is proving to be quite unreliable. It is certainly desirable to change the logic of the event recognition to give less weight to the scanning information, if any weight at all. In particular we shall try to suppress the indication about the position of the apices.
3.2 Performance of the program

So far only a small sample of the double neutral $V$ events have been measured by the HPD. A total of 31 events have been submitted to the program which recognised all of them correctly. The recognition was limited to one view of the magnetic spark chamber. Figures 6 and 7 show some other typical double neutral-$V$ events correctly recognised by the program. We consider these first results as quite encouraging and expect that the production program will be ready at the beginning of December 1964.

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References


3. P.M. Blackall, B.W. Powell and F. Zanella, "The automatic analysis of 200,000 spark chamber pictures using the CERN HPD", paper presented at this Conference.
Figure captions

Fig. 1 Schematic diagram of the experimental set-up.

Fig. 2 Schematic drawing of the magnet, of the magnet spark chamber and of the optical system.

Figs. 3 - 4 - 5 - 6 and 7 show typical photographs of two $K_1^0$ mesons decaying in the magnet spark chamber.
$S_{1,2,3,4,5,6}$, Beam Defining Counters
$R_{1,2}$, Round Anticoincidence Counters
$F_{1,2,3}$, Flat Anticoincidence Counters
$\tilde{C}_{1,2}$, Cerenkov Counters
For selection of $\pi^-, K^-$, and $\bar{p}$

Beam Momentum Defining Magnet

$\pi^-$ Trigger = $S_{1,2,3,4,5,6}, C_1, C_2, R_{1,2}, F_{1,2,3}$
$K^-$ Trigger = $S_{1,2,3,4,5,6}, C_1, C_2, R_{1,2}, F_{1,2,3}$
$\bar{p}$ Trigger = $S_{1,2,3,4,5,6}, C_1, C_2, R_{1,2}, F_{1,2,3}$

CERN Magnet Spark Chamber Test Run Layout October, 1963

Magnet Spark Chambers 180x65x65 cm$^3$
140 Plates 25 µ of Al 11 Kgauss

Fig. 1