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W. Delaney(x), A. Distante and E. Vaccari: A GENERAL PURPOSE FOR THE GEOMETRICAL RECONSTRUCTION OF SPARK CHAMBER EVENTS.

NATURE OF THE PHYSICAL PROBLEM.

The purpose of this program is to calculate the position of sparks in spark chambers based on the measurements of their projection in film in two views.

METHOD OF SOLUTION.

The calculation of the spatial coordinates of a spark is based on the geometrical relationships between the spatial position of the spark, the spatial positions of two cameras viewing the chamber containing the spark and, for each such camera, the spatial position of the intersection point of a ray from the spark to the camera with a chamber face, these intersection points being determined by homographic transformations applied to the measured spark image coordinates.

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RESTRICTIONS.

The program assumes two orthogonal views of each chamber. The number of chambers is limited only by DIMENSION statements (to 10 chambers). Similarly, DIMENSION statements limit the input data for one event to 500 words, and the maximum number of sparks per event to 20.

Otherwise the program is quite general; there are practically no restrictions on the spatial configuration of the spark chamber system, on the types of events which may be processed or on the format of the event data, such formats being specified by the user in the program input.

LONG WRITE-UP.

1. - Introduction.

The program presented here is part of a chain of programs, developed at the University of Bari, for the analysis of nuclear events in systems employing optical spark chambers as particle detectors. It has been used for the study of the pi-minus backward charge exchange at various energies and it is being used for the full solid angle study of $\bar{p}p$ annihilation in neutral and charged bosons.

In the type of experiment being considered here, a set of particles, resulting from the interaction of a beam particle in a target are observed by photographing the sparks formed as a result of the interactions of these particles in a system of particle detectors (spark chambers). Each detector is photographed in (at least) two stereoscopic views ; in this way, the spatial positions of a spark may be determined by projecting a photogram on a measuring table and measuring the table coordinates of its two images.

Fig. 1 shows the essential features of the experimental apparatus. A spark chamber, having the form of a rectangular parallelepiped is viewed in two orthogonal directions (only orthogonal views are forseen in the program GEOMP). The optic axis of each view lies in a plane parallel to the chamber plates ; it is orthogonal to a pair of chamber faces, this pair consisting of an optical face and a non-optical face where the sense of the optic axis is from the optical face to the non-optical face. On each optical face there are (at least) four fiducials (luminous marks), called optical fiducials and likewise there are (at least) two non-optical fiducials on each non optical face.

The two orthogonal views of a detector are called the direct and stereo view. Typically one physical camera is employed, each view of each chamber being realized by means of a sequence of appropriately

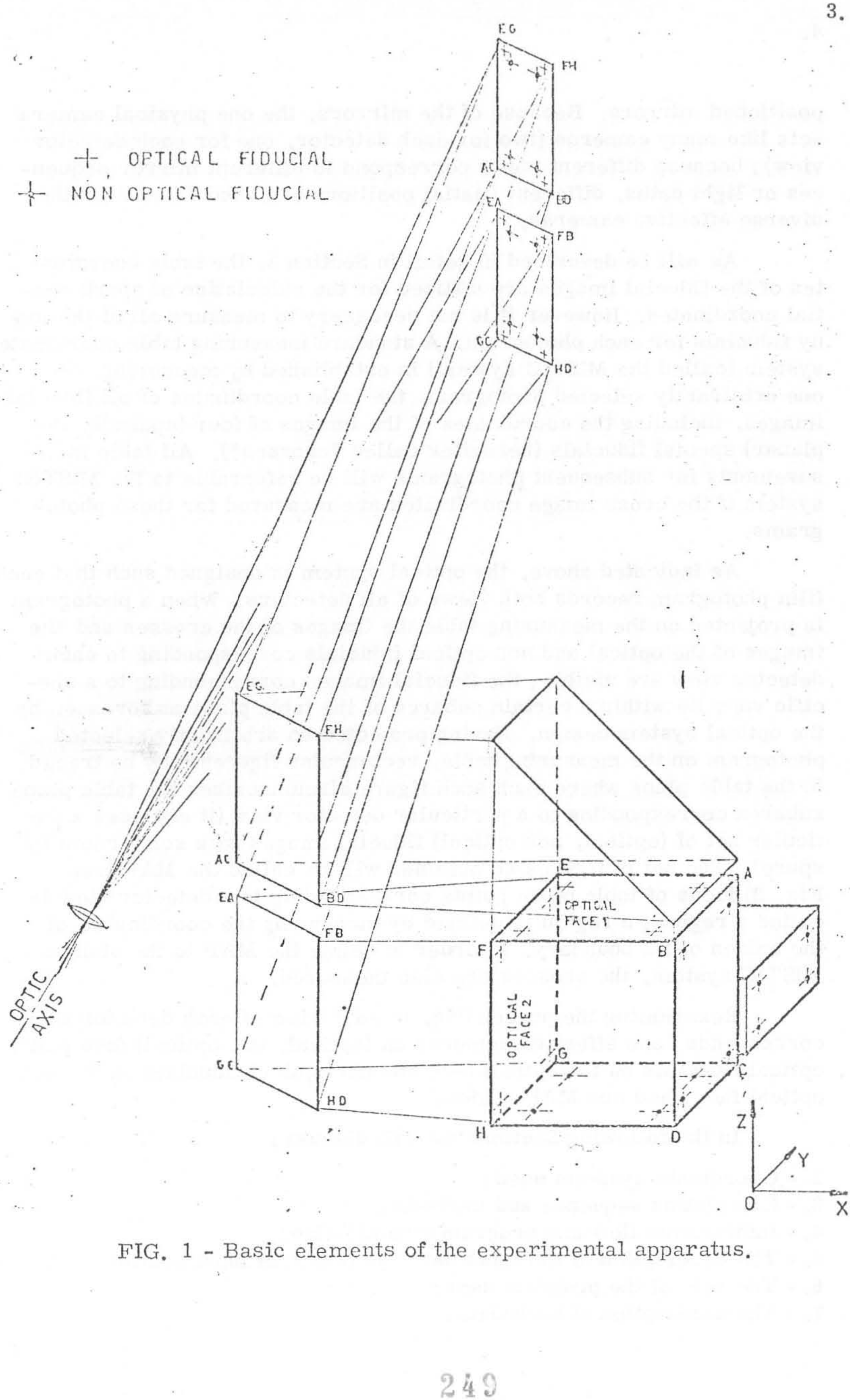

FIG. 1 - Basic elements of the experimental apparatus.

positioned mirrors. Because of the mirrors, the one physical camera acts like many cameras (two for each detector, one for each detector view); because different views correspond to different mirror sequences or light paths, different spatial positions are associated with the diverse effective cameras.

As will be described in detail in Section 3, the table coordinates of the fiducial images are utilized for the calculation of spark spatial coordinates. However it is not necessary to measure all of the many fiducials for each photogram. A standard measuring table coordinate system (called the MISTIC system) is established by measuring, for one arbitrarily selected photogram, the table coordinates of all fiducial images, including the coordinates of the images of four (spatially coplanar) special fiducials (hereafter called "crosses"). All table measurements for subsequent photograms will be referrable to the MISTIC system if the cross image coordinates are measured for these photograms.

As indicated above, the optical system is designed such that each film photogram records both views of all detectors. When a photogram is projected on the measuring table the images of the crosses and the images of the optical and non optical fiducials corresponding to each detector view are visible; the fiducial images corresponding to a specific view lie within a certain subarea of the table plane as foreseen by the optical system design. Having projected an arbitrarily selected photogram on the measuring table, rectangular figures may be traced in the table plane where each such figure circumscribes the table plane subarea corresponding to a particular detector view (it encloses a particular set of (optical, non optical) fiducial images with some room to spare). The set of figures so obtained will be called the MAP (see Fig. 2) locus of table plane points corresponding to a detector view is called a region; a region is defined by measuring the coordinates of the apices of its boundary. In order to relate the MAP to the standard MISTIC system, the crosses are also measured.

Reassuming the preceeding, to each view of each detector there corresponds: one effective camera; an (optical, non optical) face pair; optical fiducials on the optical face and non optical fiducials on the non optical face; and one MAP region.

In the following Sections we will discuss:

2. - Coordinate systems used;
3. - Calculation sequence and methods;
4. - Information flow and program organization;
5. - The description of the input data and program input section;
6. - The role of the program user;
7. - The description of bank data;

8. - The description of output data and output section;
9. - Test run and error codes.

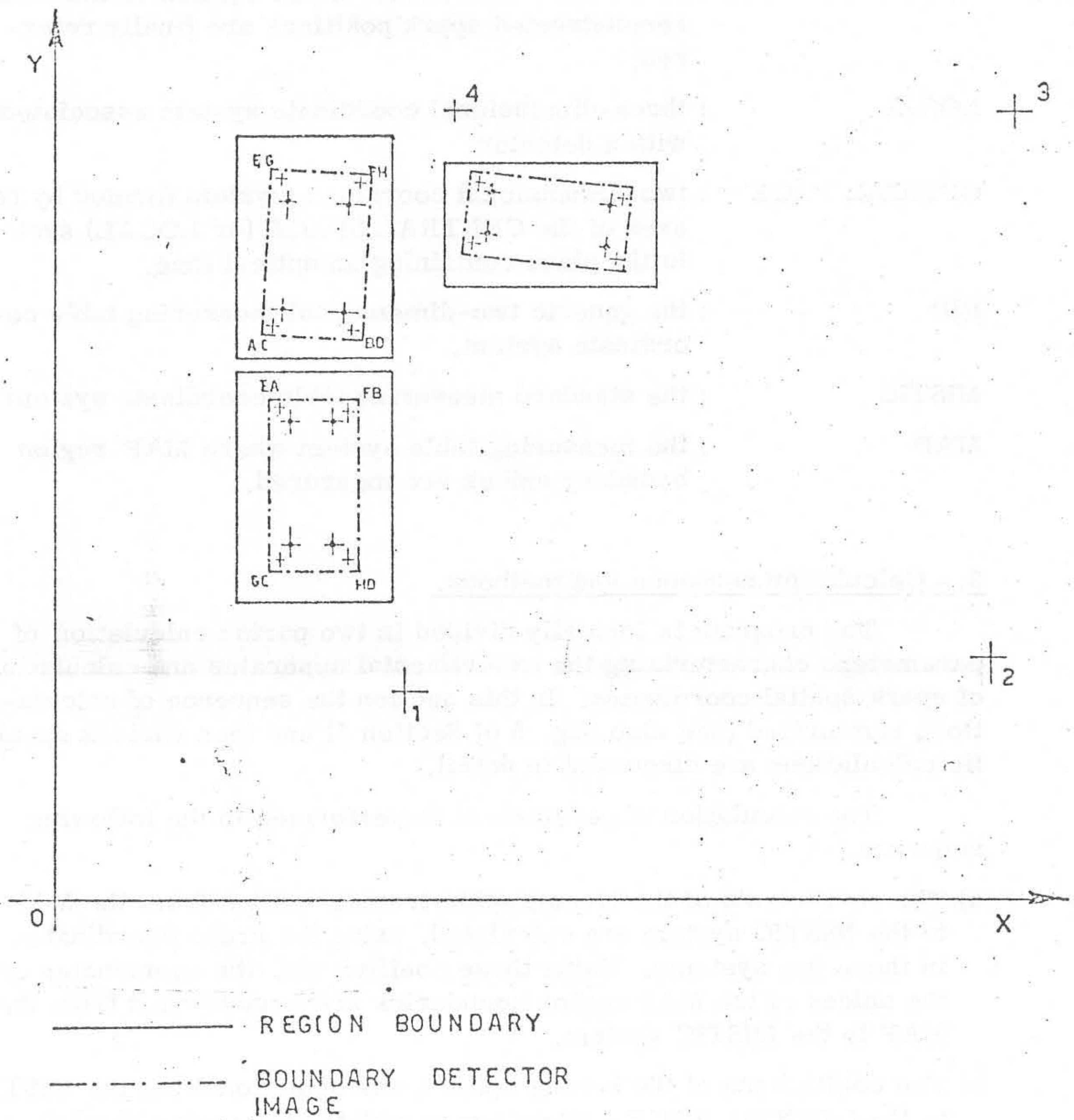

FIG. 2 - A MAP with detector images and circumscribing region boundaries.

2. - Coordinate systems.

Frequent subsequent reference will be made to the various co ordinate systems defined as follows :

CENTRAL SPACE : three-dimensional coordinate system to which all reconstructed spark positions are finally referred.

LOCAL : three-dimensional coordinate system associated with a detector.

OPTICAL FACE : two-dimensional coordinate system formed by two axes of the CENTRAL SPACE (or LOCAL) system in the plane containing an optical face.

FID : the generic two-dimensional measuring table coordinate system.

MISTIC : the standard measuring table coordinate system.

MAP : the measuring table system where MAP region boundary apices are measured.

3. - Calculation sequence and methods.

The program is logically divided in two parts : calculation of parameters characterizing the experimental apparatus and calculation of spark spatial coordinates. In this section the sequence of calculations summrized (see also Fig. 5 of Section 4) and then various specific calculations are discussed in detail.

The calculation of parameters is performed in the following sequence.

a) The coefficients of the homographic transformation from the MAP to the MISTIC system are calculated, using the cross coordinates in these two systems. Using these coefficients, the coordinates of the apices of the MAP region boundaries are transformed from the MAP to the MISTIC system.

b) The coefficients of the homographic transformation from the MISTIC to the OPTICAL FACE system are calculated for each optical face, using the coordinates of the optical fiducials in these two systems.

c) For each (optical, non optical) face pair a point on the optical face corresponding to each non optical fiducial is determined by homographically transforming the measured coordinates of the non optical fiducial from the MISTIC system to the OPTICAL FACE system (using the appropriate coefficients determined in step b)). Then the spatial coordinates of the effective camera viewing each (optical, non optical) face pair is determined using the (input) spatial coordinates of non optical fiducials, the position of their corresponding points on an optical face and the (input) measured spatial coordinates of the optical faces.

It should be noted that all spatial coordinates referred to here may optionally correspond to coordinates in a LOCAL detector system or in the CENTRAL SPACE system.

For each photogram the calculation of spark space coordinates is performed according to the following sequence.

d) The coefficients of the homographic transformation from the FID to the MISTIC system are determined using the cross coordinates measured in these systems.

e) The spark images corresponding to the direct and stereo views of the spark having been identified (see Section 6), the measured coordinates of these spark images are transformed from the FID to the MISTIC system.

f) Identifying the MAP regions containing the spark direct and stereo view images, the detector containing the spark is identified, more specifically, for each view an (optical, non optical) face pair of this detector is identified together with the effective camera viewing this face pair.

g) Using the direct and stereo view spark coordinates (now in the MISTIC system), the spatial coordinates of the cameras corresponding to these views, and the spatial coordinates of the optical faces viewed by these cameras, the spark spatial coordinates are calculated.

h) If the above spatial coordinates were LOCAL system coordinates, the spark space coordinates are finally transformed from the LOCAL system of the detector containing the spark to the CENTRAL SPACE system using (input) rotation-translation coefficients relating that LOCAL system to the CENTRAL SPACE system.

3.1. - Evaluation of homographic coefficients.

The calculation of the coefficients of the various homographic transformations referred to above is performed by a single subroutine (MIST) according to the following general procedure.

Given the coordinates of four points in two different planes, subroutine MIST computes the coefficients (a ≫ i) of the homographic transformation from the (X, Y) to the (X', Y') plane using

$$X_i' = \frac{aX_i + bY_i + c}{dX_i + eY_i + i} \quad , \qquad Y_i' = \frac{fX_i + gY_i + h}{dX_i + eY_i + i} \quad . \tag{1}$$

In formula (1), (X_i, Y_i) and (X_i', Y_i') are known for $i = 1, 4$ and considering that one of the coefficients can take any arbitrary value, the problem is simply to solve a system of 8 linear equations in 8 unknowns; this is accomplished by inverting the matrix of the coefficients and multiplying by the vector of known terms.

3.2. - Calculation of camera position.

The geometrical relationships utilized for the determination of the effective camera position are shown in Fig. 3 ; P and Q are non optical fiducials with images P" and Q" in the film plane of the camera (the plane containing the MISTIC system).

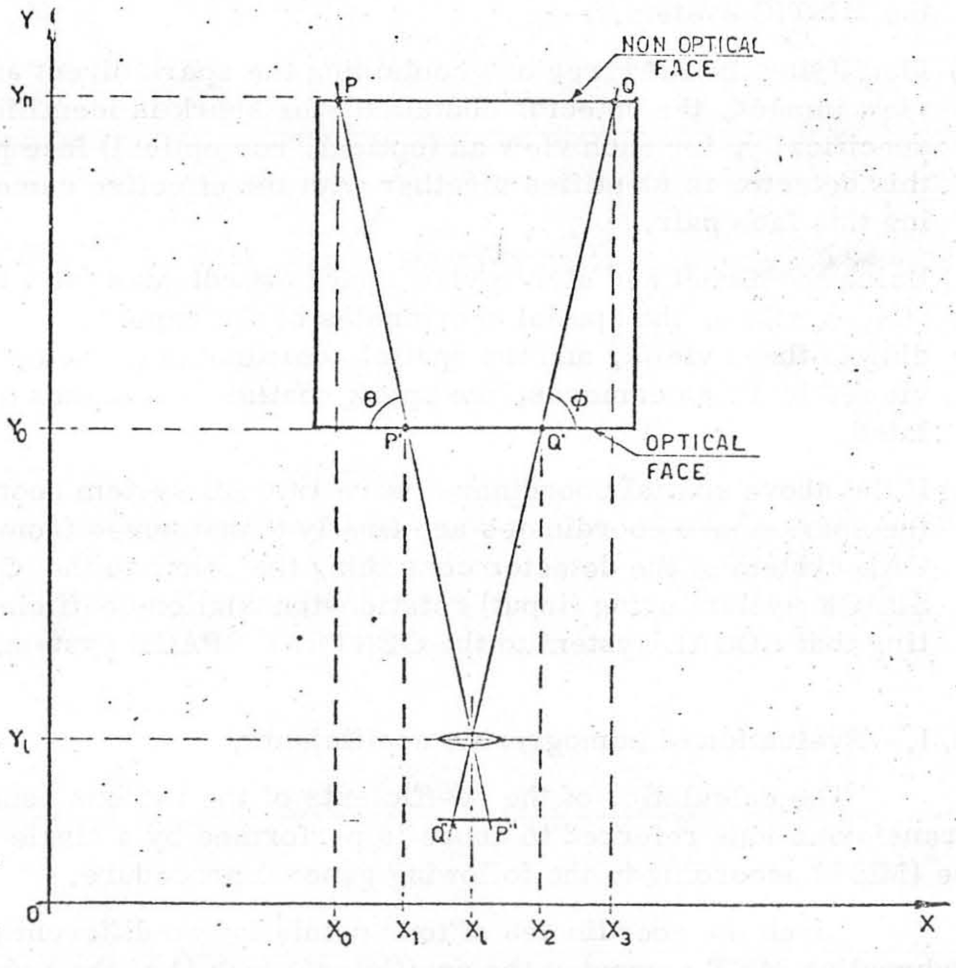

FIG. 3 - A camera viewing a spark chamber. The camera coordinates X_2, Y_2 are determined by the coordinates of the fiducials P, Q, P' and Q' as in Eq. (2) and (3) of the text.

The points P' and Q' are respectively the intersection points of the rays PP" and QQ" with the detector optical face viewed by the camera. The coordinate X_1 of point P' is determined by homographically transforming the (MISTIC system) coordinates of image P" to the optical face, in the same way the coordinate X_2 of point Q' is determined.

Using the known spatial coordinate Y_o of the optical face and the known spatial coordinates (Y_N, X_o) and (Y_N, X_3) of the non optical face fiducials (all in an arbitrary XYZ system), the spatial camera (lens) coordinates (Y_L, X_L) are determined as follows.

From the geometry of the figure :

$$\tan\theta = (Y_o-Y_L)/(X_1-X_L) = (Y_N-Y_o)/(X_o-X_1) ,$$

$$\tan\phi = (Y_o-Y_L)/(X_2-X_L) = (Y_N-Y_o)/(X_3-X_2) .$$

Solving for Y_L and X_L ,

$$Y_L = Y_o-(Y_N-Y_o)(X_2-X_1)/(X_3+X_1-X_2-X_o) \qquad (2)$$

$$X_L = X_1+(Y_o-Y_L)(X_1-X_o)/(Y_N-Y_o) = X_2+(Y_o-Y_L)(X_2-X_3)/(Y_N-Y_o) . \qquad (3)$$

The homographic transformations referred to above yield also the Z coordinates of the points P' and Q' on the optical face. The geometrical relationships in the YZ plane are completely analoguous to those in the YX plane ; replacing the X's by Z's in Fig. 3,

$$Y_L = Y_o-(Y_N-Y_o)(Z_2-Z_1)/(Z_3+Z_1-Z_2-Z_o) , \qquad (4)$$

$$Z_L = Z_1+(Y_o-Y_L)(Z_1-Z_o)/(Y_N-Y_o) = Z_2+(Y_o-Y_L)(Z_2-Z_3)/(Y_N-Y_o) . \qquad (5)$$

For each pair of fiducials on a non optical face, the expressions (2), (3), (4), (5) yield two values for Y_L and one for X_L and Z_L. The camera coordinates may be calculated by averaging the values of (X_L, Y_L, Z_L) determined for the diverse non optical fiducial pairs. The camera coordinates obtained according to the above procedure will be in the CENTRAL SPACE (or LOCAL) coordinate system to which the (input) spatial coordinates of the optical face, and non optical fiducials, are referred.

With the above method small inaccuracies in fiducial coordinate measurements or small imperfections in the optical system may result in large inaccuracies in the determination of the camera coordinate (Y_L) in the direction orthogonal to the optical face. For this reason the expressions (2), (4) are not used for the determination of this coordinate. Instead, its value is specified (for each effective camera) in the program input. (The input value is the length of the optical path through the sequence of mirrors which corresponds to the effective camera).

3.3. - Space point reconstruction.

Fig. 4 displays the geometrical relationships utilized for the calculation of spark space coordinates. Light rays from a point (spark) P in the detector form the images P_1 and P_2 respectively in the (MISTIC) film planes of two cameras, these planes having coordinates Y_f and X_f in an arbitrary XYZ coordinate system.

The coordinate X_2 of the intersection of ray PP_1 with optical face 1 is determined by homographically transforming coordinates of the image P_1 from its MISTIC plane to optical face 1; similarly the coordinate Y_2 is determined from the homographic transformation of image P_2.

Using the coordinates X_2 and Y_2 together with the space coordinates Y_o and X_o of the optical faces and the space coordinates (X_1, Y_L) and (X_L, Y_1) of the cameras, the spark space coordinates (X_3, Y_3) are determined as follows.

From the geometry of Fig. 4 :

$$\tan\theta = (Y_o - Y_L)/(X_2 - X_1) = (Y_3 - Y_o)/(X_3 - X_2),$$

$$\tan\phi = (X_o - X_L)/(Y_2 - Y_1) = (X_3 - X_o)/(Y_3 - Y_1).$$

Evaluating these expressions for X_3 and Y_3,

$$X_3 = \frac{Y_o - Y_2 + X_o(Y_2 - Y_1)/(X_o - X_L) - X_2(Y_o - Y_L)/(X_2 - X_1)}{(Y_2 - Y_1)/(X_o - X_L) - (Y_o - Y_L)/(X_2 - X_1)},$$

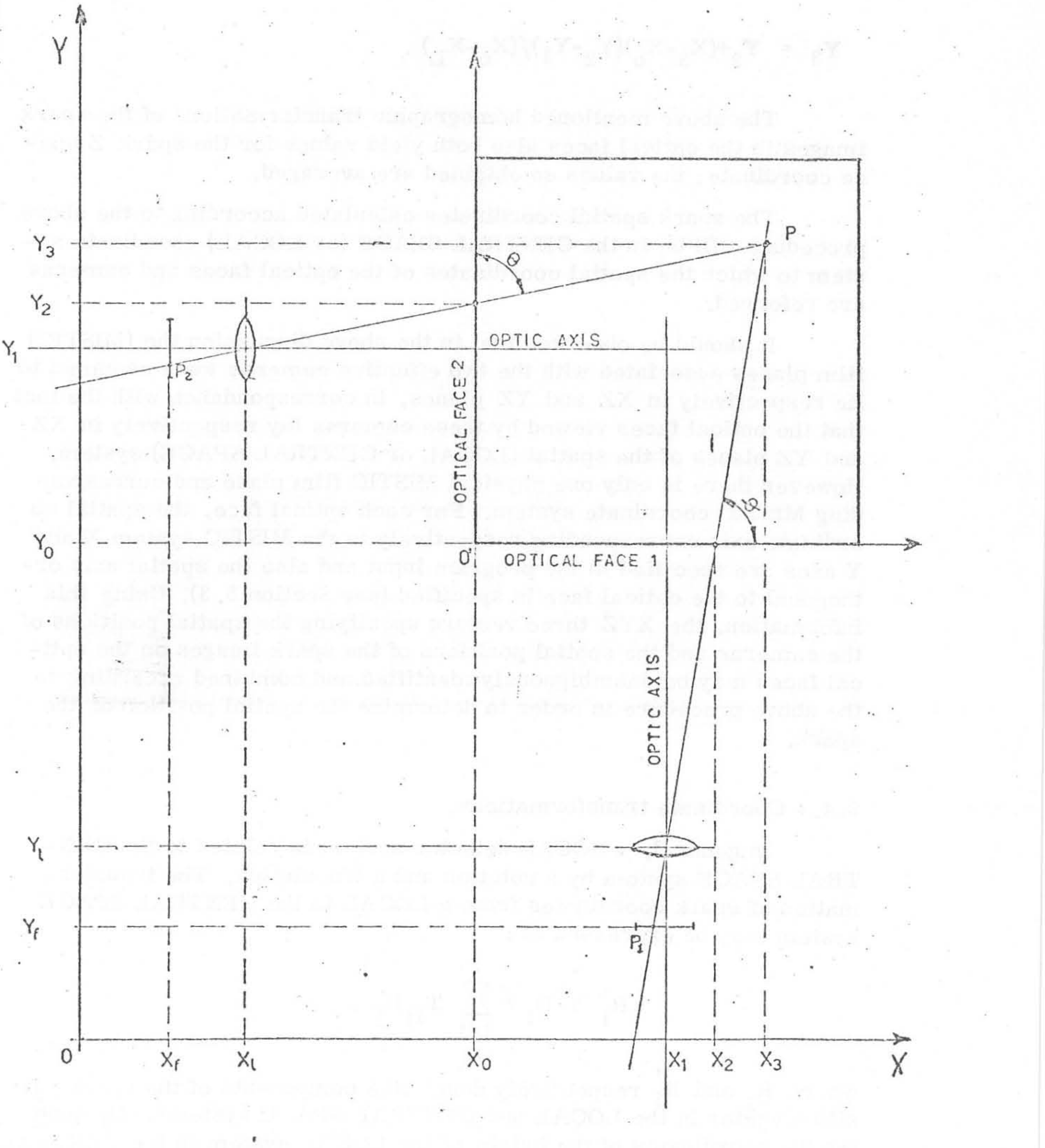

FIG. 4 - The geometrical relationships between a spark P in a spark chamber and its images P_1 and P_2 on film, useful for the determination of the spark spatial coordinates as discussed in the text.

$$Y_3 = Y_2 + (X_3 - X_o)(Y_2 - Y_1)/(X_o - X_L) .$$

The above mentioned homographic transformations of the spark images to the optical faces also both yield values for the spark Z space coordinate ; the values so obtained are averaged.

The spark spatial coordinates calculated according to the above procedure will be in the CENTRAL SPACE (or LOCAL) coordinate system to which the spatial coordinates of the optical faces and cameras are referred.

It should be observed that in the above discussion the (MISTIC) film planes associated with the two effective cameras were assumed to lie respectively in XZ and YZ planes, in correspondance with the fact that the optical faces viewed by these cameras lay respectively in XZ and YZ planes of the spatial (LOCAL or CENTRAL SPACE) system. However there is only one physical MISTIC film plane and corresponding MISTIC coordinate system. For each optical face, the spatial coordinate axis corresponding respectively to the MISTIC system X and Y axes are specified in the program input and also the spatial axis orthogonal to the optical face is specified (see Section 5. 3). Using this information, the XYZ three vectors specifying the spatial positions of the cameras and the spatial positions of the spark images on the optical faces may be unambiguously identified and combined according to the above procedure in order to determine the spatial position of the spark.

3. 4. - Coordinate transformations.

In general, a LOCAL detector system is related to the CENTRAL SPACE system by a rotation and a translation. The transformation of spark coordinates from a LOCAL to the CENTRAL SPACE system may be expressed as :

$$R'_i = D_i + \sum_{i=1}^{3} T_{ij} R_j ,$$

where R_j and R'_i respectively denote the components of the spark position vector in the LOCAL and CENTRAL SPACE systems, D_i denotes the coordinates of the origin of the LOCAL system in the CENTRAL SPACE system, and T_{ij} denotes an element of the rotation matrix, corresponding to the cosine of the angle between axis i of the LOCAL system and axis j of the CENTRAL SPACE system.

4. - Information flow and program organization.

The information flow from the required input data to the reconstructed space point (spark position) is shown in Fig. 5 ; in the diagram, boxes at the end point of arrows are the results of calculations which depend on boxes at the beginning of the arrows. Basic input data to the program corresponds to a box with only outgoing arrows. Within each box the result is identified ; the coordinate system or systems to which it pertains is given in parenthesis, an arrow indicating the sense of coordinate system transformations as appropriate.

In the figure, the general case where all input spatial coordinates are referred to LOCAL detector systems is assumed ; if these coordinates are input in the CENTRAL SPACE system the word "LOCAL" should be read "CENTRAL SPACE" and obviously the final coordinate transformation from the LOCAL to the CENTRAL SPACE system is unnecessary.

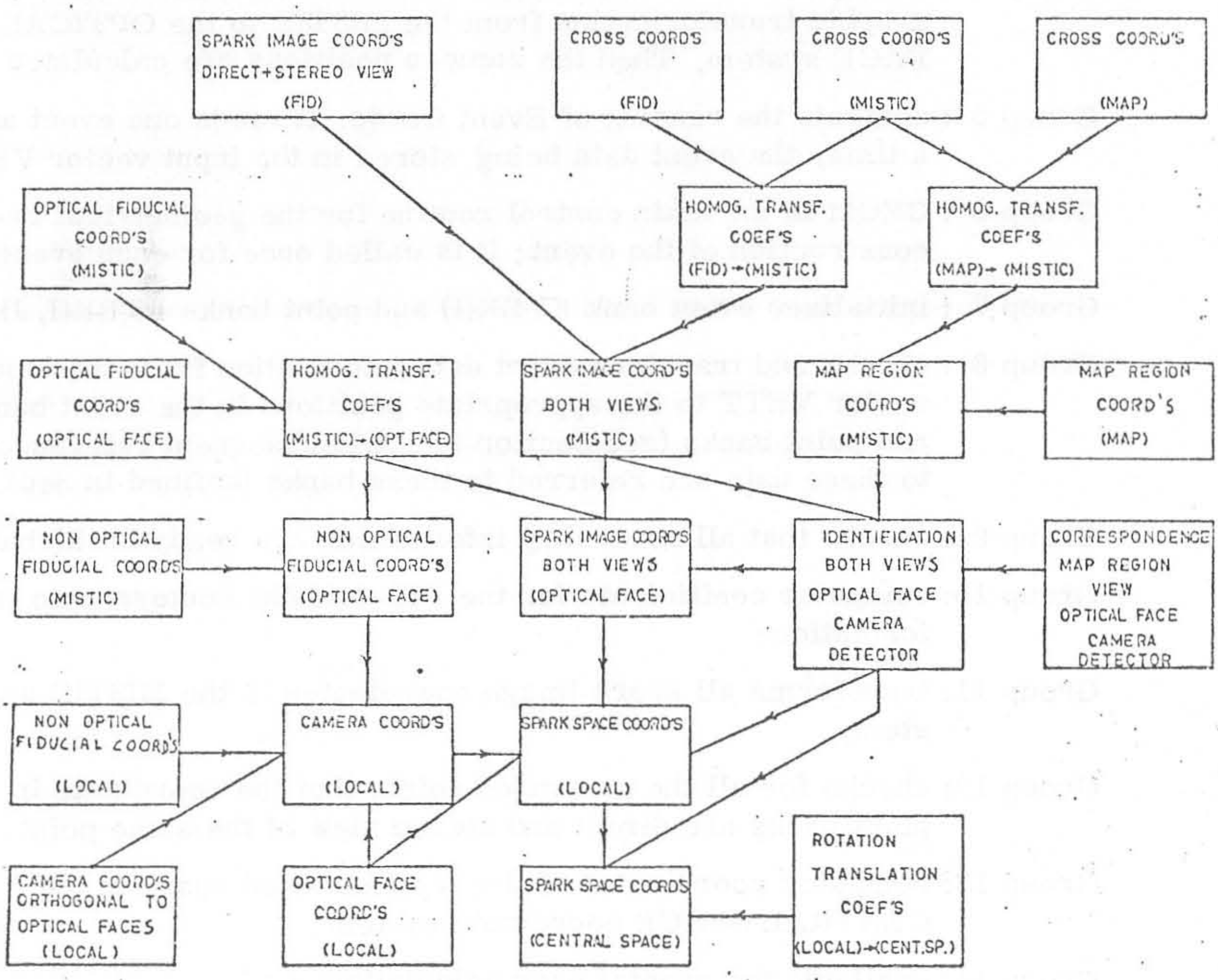

FIG. 5 - The information flow from the input date to the spark space coordinate calculation.

Fig. 6 displays the logical organization of the program in the form of a flow chart. The numbers 1-15 identify groups of routines; each such group performs a specific higher level function or functions, these group functions being summarized in the following.

Group 1 : reads and interprets Control Cards (see Section 5.1), specifying general run parameters;

Group 2 : reads Parameter Cards defining the MAP, various coordinate systems and camera positions (see Section 5.2), computes a set of homographic coefficients to transform from the MAP system to the MISTIC system; transforms region apex coordinates from the MAP system to the MISTIC system;

Group 3 : reads Experimental Data Cards (see Section 5.3) defining the particle detectors;

Group 4 : for all optical faces, computes the coefficients of the homographic transformation from the MISTIC to the OPTICAL FACE system. Then the camera positions are calculated;

Group 5 : controls the reading of Event Cards. It reads one event at a time, the event data being stored in the input vector VETT;

Group 6 : GEOM is the main control routine for the geometrical reconstruction of the event; it is called once for each event;

Group 7 : initializes event bank EVBK(I) and point banks PTBK(I, J);

Group 8 : checks and transfers event data information from the input vector VETT to the appropriate positions in the event bank and point banks (see Section 6). All subsequent references to these data are referred to these banks (defined in Sect. 7);

Group 9 : checks that all necessary information are ready in the banks;

Group 10: computes coefficients for the FID-MISTIC homographic transformation;

Group 11: transforms all spark image coordinates to the MISTIC system;

Group 12: checks for all the measured points that the coordinate in point banks are direct and stereo view of the same point;

Group 13: computes coordinates of the reconstructed spark in the CENTRAL SPACE coordinate system;

Group 14: available for special user calculations;

Group 15: outputs results (see Section 9).

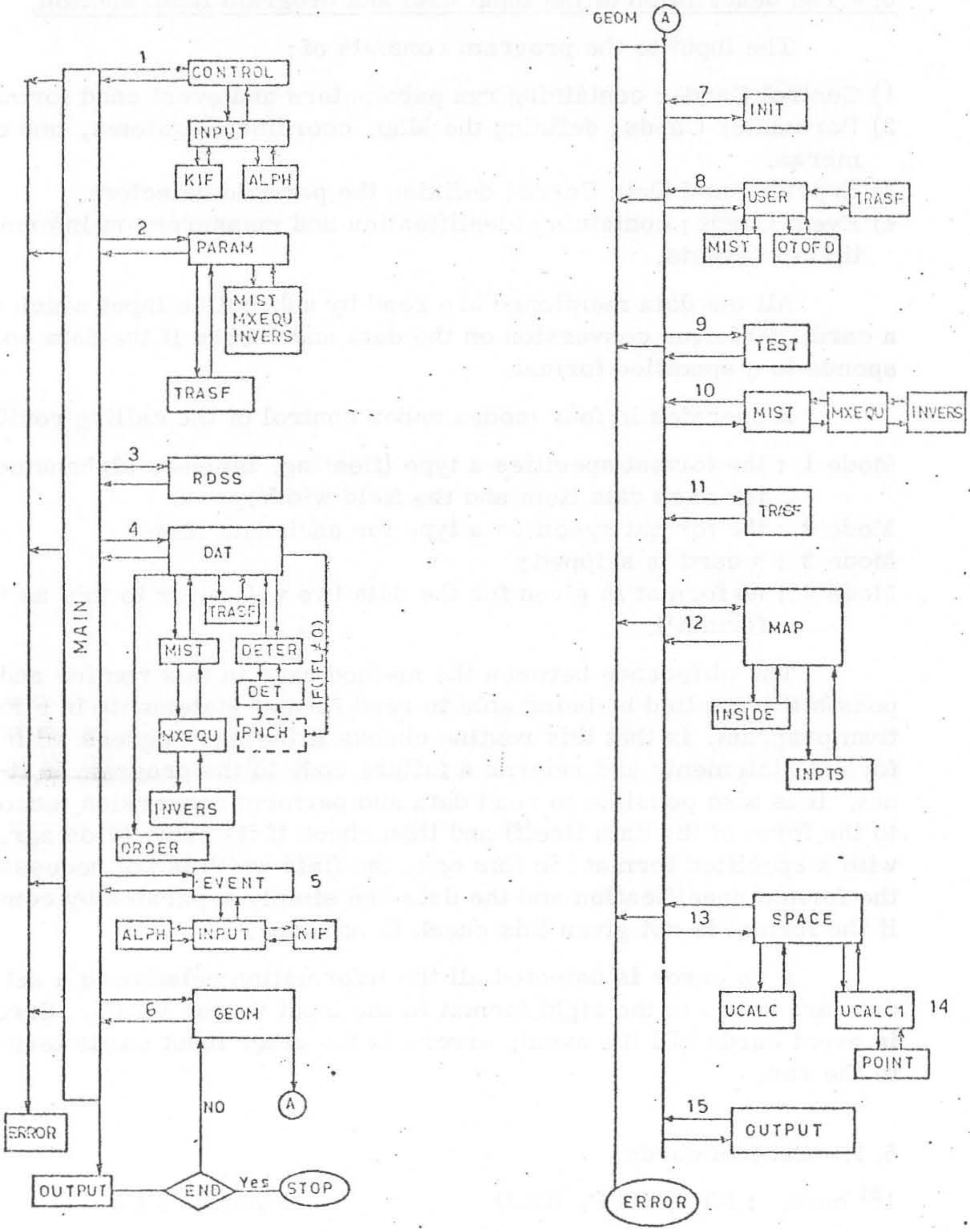

FIG. 6 - Program general flow chart. Numbers 1-15 identify groups of routines, each such group performing a specific higher level function as explained in the text.

5. - The description of the input data and program input section.

The input to the program consists of:

1) Control Cards; containing run parameters and event card formats.
2) Parameter Cards; defining the Map, coordinate systems, and cameras.
3) Experimental Data Cards; defining the particle detectors.
4) Event Cards; containing identification and measurement information for events.

All the data mentioned are read by subroutine Input which reads a card, performs conversion on the data and checks if the data corresponds to a specified format.

It operates in four modes under control of the calling routine:

Mode 1 : the format specifies a type (floating, integer, alphanumeric) for each data item and the field width;
Mode 2 : the format specifies a type for each data item;
Mode 3 : a card is skipped;
Mode 4 : no format is given for the data (we will refer to this as 'free format').

The difference between the method used in this routine and the possibility implied by being able to read format statements in a Fortran program, is that this routine checks if the input agrees with the format statements and returns a failure code to the program if it does not. It is also possible to read data and perform conversion (according to the form of the data itself) and then check if its conversion agrees with a specified format; in this case the field width is not necessary in the format specification and the data are simply separated by commas, if the format is not given this check is not done.

If no error is detected all the information relative to a set of data are saved in the right format in the input vector VETT. Errors in event cards kill the event, errors in the other input cards terminate the run.

5.1. - Control cards.

1st card : NTT, NTP, IOLD   Format 3 I 5

information about tape units:

NTT unit number for binary output

NTP unit number for BCD output

IOLD flag = 0 if the binary output must be added to an old output tape.

2^{nd} card : identification card. From 1 to 80 alphanumeric characters. These information are written as first record on the BCD output and on the binary output.

3^{rd} card : KIND, IFL1, LFLAG Format 3 I 5

KIND = { 1 read parameters (4), (5) section 3. 2
         2 compute parameters (4), (5) section 3. 2

IFL1 $\neq$ 0 and KIND = 2 parameter cards will be punched

LFLAG : flag specifying if the measurements defining the geometry of the experimental apparatus are given in CENTRAL SPACE (LFLAG = 0) or LOCAL (LFLAG = 1) system.

4^{th} card : IMOD, IDIM, N, IFL Format 4 I 5

IMOD flag specifying if the measurements relative to one event (in the FID system) obey a given format or if they are simply separated by commas;

IMOD = 1 with format
       2 without format.

IDIM maximum possible number of information relative to 1 event

N number of control cards following

IFL flag specifying if the measurements (in FID system) are in octal (IFL = 8) or decimal (IFL = 10).

5^{th} to $(4+N)^{th}$ card: "Format cards" specifying formats for the event data cards. A format card, itself in 'free format' with the general form $n_1T_1w_1, n_2T_2w_2, \ldots$, describes a data card containing n_1 data items of type T_1 and field width w_1 followed by n_2 data items of type T_2 and field width w_2, etc., where the T_i may be the letters I (Fortran integer) or F (Fortran "F" format).

$(5+N)^{th}$ card : associates the format cards with the event data cards. It is in 'free format' with the general form $n_1(L)$, $n_2(J), \ldots$, signifying that the set of cards for one event is composed of n_1 cards having the format specified by the L^{th} format card, followed by n_2 cards having the format specified by the J^{th} card, etc.

5.2. - Parameter cards.

These cards consist of:

(1) set of parameters defining regions of the photogram; cards (2-4) are repeated for all MAP regions.

NAME	CARD	FORMAT/COLUMNS		MEANING
NREG	1	I5	1-5	Number of regions in the MAP
IRD	2	I10	1-10	Serial region number direct view
IFACE		I10	11-20	Optical face serial number (1 or 2) for this region
IRS		I10	21-30	Serial region number stereo view
IPRP		I10	31-40	1, 2, 3 if x, y, z axis is perpendicular to the optical face
NP		I10	41-50	Number of coordinate pairs which define this region
IDT		I10	51-60	Serial number of detector associated to this region
ICOOR	3	5(2I5, X)	10-65	Region apex coordinates, MAP system
ICROD	4	5(2I5, X)	10-65	Coordinates of crosses in MAP system.

(2) set of parameters specifying rotation matrices and translation vectors for transformation of points from LOCAL system to CENTRAL SPACE system - if LFLAG = 0 the set of cards (2-5) must be omitted (otherwise they are repeated for all detectors).

NAME	CARD	FORMAT/COLUMNS		MEANING
NDS	1	I10	1-10	Number of detectors
DD(I, K)	2	3F10	1-30	For I = (1, 2, 3), (x, y, z) origin of LOCAL system K in CENTRAL SPACE system

NAME	CARD	FORMAT/COLUMNS		MEANING
TT(I, 1, K)	3	3F10	1-30	$TT(I, J, K) = \cos \theta^K_{IJ}$, θ^K_{IJ} = angle between axis I of LOCAL system K and axis J of CENTRAL SPACE system.
TT(I, 2, K)	4			
TT(I, 3, K)	5			

(3) number and coordinates of crosses measured in the MISTIC coordinate system.

NAME	CARD	FORMAT/COLUMNS		MEANING
NPS	1	I5	6-10	Number of measured crosses
VPS	2	10F8	1-80	Coordinates (x, y) of crosses

If the program is running with parameter KIND = 1, also the following data must be provided within the Parameter Cards ;

(4) sets of homographic coefficients to transform from MISTIC coordinate system to OPTICAL FACE coordinate systems, and

(5) apparent camera positions relative to the optical faces of a detector. Cards (1-4) are repeated for each detector, (2-4) for each optical face.

NAME	CARD	FORMAT/COLUMN		MEANING
NFS(K)	1	I5	6-10	Number of optical faces for detector K
NPRF(J)	2	I5	6-10	1, 2, 3 if x, y, z axis CENTRAL SPACE (or LOCAL) system is perpendicular to optical face J
CCS(I, J, K)		F10	11-80	Camera coordinates (I = = 1, 3)
NCX	3	I5	6-10	Number of homographic coefficients relative to face J of detector K
HCF(M, J, K)	4	F10	1-80	Homographic coefficients (M = 1, NCX).

5.3.- Experimental data cards.

If the program is running with parameter KIND = 2, the following data must be provided for each detector. The set of cards (2-4) is repeated for each face. The cards pertaining to a non optical face must immediately follow those for its corresponding optical face.

NAME	CARD	FORMAT/COLUMN		MEANING
NFS	1	I10	1-10	Number of faces
NRF	2	I10	1-10	Sequencial face number
KPRF		I10	11-20	1, 2, 3 if x, y, z axis CENTRAL SPACE (or LOCAL) coordinate system is orthogonal to this face
NF		I10	21-30	Number of fiducial lights on this face
IOPF		I10	31-40	Flag = 0 if this face is optical
IDST		I10	41-50	Camera coordinate normal to face, ignored if IOPF non zero
ITT		I10	51-60	1, 2, 3 if x, y, z axis CENTRAL SPACE (or LOCAL) coordinate system is parallel to MISTIC system x axis
IVV		I10	61-70	1, 2, 3 if x, y, z axis CENTRAL SPACE (or LOCAL) coordinate system is parallel to MISTIC system y axis
POSI		F10	71-80	Coordinate of optical face plane in CENTRAL SPACE (or LOCAL) system
FDX	3	F8	1-80	Fiducial coordinates (x, y) in MISTIC system
FIDU	4	F8	1-80	Fiducial coordinates (x, y, z) in CENTRAL SPACE (or LOCAL) system.

5.4. - Events cards.

These cards contain the information necessary to identify one event (see Section 6), the measurements of the images of sparks to be reconstructed and the measurements of the images of crosses ; these measurements are in the FID coordinate system.

6. - The role of the program user. -

6.1. - Subroutine user.

The strategy used for the input of event data may be summarized as follows. Using the format information specified on the Control Cards, subroutine Input reads all the event data into a vector VETT. Then, in subroutine User, the user transfers these data into an event bank, EVBK, and point banks, PTBK ; all quantities for subsequent calculations are taken from these banks.

The first card for an event contains general information about the event and following cards contain coordinate pairs for measured points (crosses and sparks). The contents of EVBK and the PTBK are defined in Section 7 ; where the quantities which should be set in User are indicated.

As necessary, the general event information may include quantities defining the expected number of cross coordinates and spark image coordinates. Using this information and a mesurement sequence convention, subroutine User knows how many and which coordinate data to transfer to the EVBK and PTBK banks (in particular, the coordinates referring to the direct and stereo views of the same spark may be identified) and errors in the event data may be detected (User may return an error code which kills the event - see Section 9).

The region number limits PTBK (13) and PTBK (14) associated with a spark may be usefull (for detecting errors) when the user has a-priori knowledge as to the possible locations of certain images. Otherwise, these limits would just correspond to the first and last region number.

User must transfer the cross coordinates to EVBK and the spark image coordinates to the PTBK and must define EVBK (25), EVBK (26). If these quantities are not defined the event will be killed.

The general event information may include event identification information such as roll and frame number (EVBK(1) - EVBK(24)) and an event type code identifying particle codes to be associated with sparks (PTBK(1)). PTBK(1) and EVBK(1)-EVBK(24) are not used by the program but since they are written on the binary output, they should be set if the user wishes to record this information.

6. 2. - Subroutine Ucalc.

At the end of each event, when all the event information exists in the EVBK and PTBK banks, subroutine Ucalc is called. At this point the user can do any desired calculation utilizing the bank data. The results of such calculations may be stored in EVBK(38)-EVBK(50) if it is desired that these results be preserved on the binary output tape.

Before doing any calculations, Ucalc should check the error code stored in EVBK(37) to see if the event had been killed.

7. - The description of bank data. -

For each event which is analyzed the program builds one 'event bank' and a number of 'point banks' equal to the number of physical sparks. These banks summarize the more important information pertinent to an event; some of these quantities, at the end of each event, are written on tape (see Section 8).

Event Bank (EVBK)

LOCATION	TYPE	SET IN	DESCRIPTION
EVBK(1)	I	USER	Information relative to the identification of the event like frame, roll, date, special flags, event type code, particle type code, etc.
EVBK(1)		USER	
EVBK(24)		USER	
EVBK(25)	I	USER	Number of measured spark images
EVBK(26)	I	USER	Number of measured cross images
EVBK(27)	F	USER	(x, y) cross coordinate pairs
EVBK(27)	F	USER	
EVBK(36)	F	USER	
EVBK(37)	I	ERROR	Error code (see error code list, (Section 9)
EVBK(38)		UCALC	Available for results of special calculation performed by the user
EVBK(38)		UCALC	
EVBK(50)		UCALC	

Point Bank (PTKB)

LOCATION	TYPE	SET IN	DESCRIPTION
PTBK(1)	I	USER	Code
PTBK(2)	F	USER	Spark image x coordinate direct view (FID system)
PTBK(3)	F	USER	Spark image y coordinate direct view (FID system)
PTBK(4)	I	MAP	Serial region number direct view
PTBK(5)	I	MAP	Optical face serial number for direct view
PTBK(6)	I	MAP	1, 2, 3 if direct view optic axis parallel to x, y, z space axis
PTBK(7)	I	MAP	1, 2, 3 if stereo view optic axis parallel to x, y, z space axis
PTBK(8)	I	MAP	Number of detector containing spark
PTBK(9)	I	MAP	Optical face serial number for stereo view
PTBK(10)	F	USER	Spark image x coord. stereo view (FID system)
PTBK(11)	F	USER	Spark image y coord. stereo view (FID system)
PTBK(12)	I	MAP	Serial region number stereo view
PTBK(13)	I	USER	Lower limit region number
PTBK(14)	I	USER	Upper limit region number
PTBK(15)	F	GEOM	Spark image x coord. direct view (MISTIC system)
PTBK(16)	F	GEOM	Spark image y coord. direct view (MISTIC system)
PTBK(17)	F	GEOM	Spark image x coord. stereo view (MISTIC system)
PTBK(18)	F	GEOM	Spark image y coord. stereo view (MISTIC system)
PTBK(19)	F	SPACE	Spark image x coord. direct view (OPTICAL FACE system)

LOCATION	TYPE	SET IN	DESCRIPTION
PTBK(20)	F	SPACE	Spark image y coord. direct view (OPTICAL FACE system)
PTBK(21)	F	SPACE	Optical face coordinate direct view
PTBK(22)	F	SPACE	Spark image x coord. stereo view (OPTICAL FACE system)
PTBK(23)	F	SPACE	Spark image y coord. stereo view (OTPICAL FACE system)
PTBK(24)	F	SPACE	Optical face coord. stereo view
PTBK(25)	F	SPACE	x } coordinates of the reconstructed spark point in CENTRAL SPACE system
PTBK(26)	F	SPACE	y
PTBK(27)	F	SPACE	z

8. - The description of the output data and output section. -

Here the binary and hard copy (BCD) program ouput are described.

The BCD output consists of:

a) the control Cards (see Section 5. 1);
b) the Parameter Card input data;
c) the Experimental data input;
d) for each event: the event error code and, for each spark in the event, the associated error code, measured direct and stereo view film coordinates and reconstructed spatial coordinates;
e) a summary of the run after all events have been processed.

Section 9 contains an example of this output.

The subroutine Output (IND) writes the binary output tape under control of the argument (IND). First a label record is written (IND=1), the record being a copy of the second Control Card. Then one event record is written for each event (IND=2). Finally, an end of file is written (IND=3). The label and event record formats and contents are as follows.

LABEL RECORD:

WORD	CONTENTS
1	Number of words in the record minus one
2-21	The second Control Card, four card characters per word

EVENT RECORD :

WORD	CONTENTS
1	Number of words in the record minus one
2	Number of words from the event bank
3	Number of point banks for the event
4	Number of words from each point bank
5-54	Event bank EVBK(I), I = 1, 50
55	PTBK(1)
56	PTBK(8)
57-59	PTBK(25), PTBK(26), PTBK(27)
60	PTBK(2)
61	PTBK(3)
62, 63	PTBK(10), PTBK(11)

Words 55-63 are repeated for all point banks utilized for the event.

9. - Error codes .-

The following Table I displays errors which may be detected by the program. Values of the error code, IFAIL, greater than fifty kill an event; the value of this code is written (by subroutine ERROR), for each event and for each point on the BCD and binary output. Unused values of IFAIL may be utilized in subroutine User (where the user must recall that IFAIL values greater than fifty kill an event).

TABLE I

Errors, their codes, sources and significances.

IFAIL	ROUTINE	MEANING
20	MAP	Direct view image found in region differing from region set in User for that image
21	MAP	Stereo view image found in region differing from region set in User for that image
61	TEST	No spark image measurements
63	TEST	Spark image coordinate missing
65	TEST	Overflow array dimension
66	TEST	Optic axis identifier (PTBK(6)) out of range
71	MAP	Direct view spark image not contained in any map region

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IFAIL	ROUTINE	MEANING
72	MAP	Stereo view sparl image not contained in any map region
73	MAP	Direct and stereo view spark images found in regions not corresponding to a stereo view pair
74	MAP	Direct view region number out of allowed range (as set in User)
80	SPACE	The two views of a spark are inconsistent (inequality of space coordinate common to both views)
100	EVENT	Event data overflows input vector (VETT)
101	INPUT	Data disagree with specified format
102	CONTRL	Error in control cards
105	PARAM	Error in parameter cards
106	RDSS	Error in experimental data cards.