A MATCH PACKAGE

for

THE ANL THREE-VIEW GEOMETRY PROGRAM

by

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Users Guide

The ANL MATCH package consists of a set of 13 subroutines which are linked to the current 12-foot and 15-foot versions of the ANL TVGP program. Their purpose is to match the tracks from the various measured views to obtain a proper matched set of tracks to be processed by TVGP. The MATCH package can effectively handle up to 20 tracks per event measured in 2 or 3 views and in cases of ambiguous match solutions, allow up to 10 match ambiguities. A basic assumption made is that the same number of tracks are measured in each view. MATCH can work in either two or three measured views with the assumption that if only two views are measured, the last point measured on each track is a good representation of the true end-point of the track. This is not to say however that if this assumption is false that MATCH cannot obtain a match solution. It is true, however, that the probability of obtaining a match solution is inversely proportional both to the number of tracks per vertex and to the momentum of the tracks. Current uses of MATCH are in obtaining match solutions for two-view K^-p (6.5 GeV/c) events measured on POLLY III and in obtaining match solutions for events with large numbers of tracks (3-10) produced by an $\bar{\nu}p$ interaction in the FNAL 15-foot bubble chamber with a spectrum of momentum values ranging from 5 - 25 GeV/c. Future plans are for the current MATCH package to be incorporated into the POLLY III software to be used as part of an on-line TVGP program.

The MATCH package is called from the TVGP routine REDGEN and uses blank common and the labelled common blocks /OPTC12/ and /ANLIN/ of TVGP. Changes to REDGEN and/or the three common blocks mentioned must be considered if MATCH is to be used properly. The user is expected to supply a subroutine ETSUB to relate to MATCH the number of vertices in the current event and the number of tracks at each vertex. (See the detailed write-up for ETSUB.) A set of two MATCH data cards read from logical unit 5 is expected and must be supplied by the user. The various data values to be entered and the proper format are detailed in subroutine MACON. Debug facilities are incorporated in the MATCH package and the degree of printout produced is dependent on the TVGP print flag parameter IBCPAR(16).

IBCPAR(16) $<$ 10	-	No debug printout
10 $\leqslant$ IBCPAR(16) $<$ 50	-	Full debug printout from MATCH
IBCPAR(16) $\geqslant$ 50	-	Full debug printout from MATCH and the logic handling subroutine CLEAR3.

The full debug option capability can produce excessive printout for events which have a large number of tracks and should only be used in the initial phase of TVGP processing to determine the necessary MATCH constants. A sample printout of the debug option is produced at the end of this report. Further diagnostics may be obtained from a proper use of the dummy supplied routine MATPLT (see detailed write-up). A possible printout using MATPLT follows the debug printout. The two data cards read in by MATCH should be the last two cards of the input data stream from unit 5. A sample of the current data values used by the K^-p and $\bar{\nu}p$ experiments are shown in Table I.

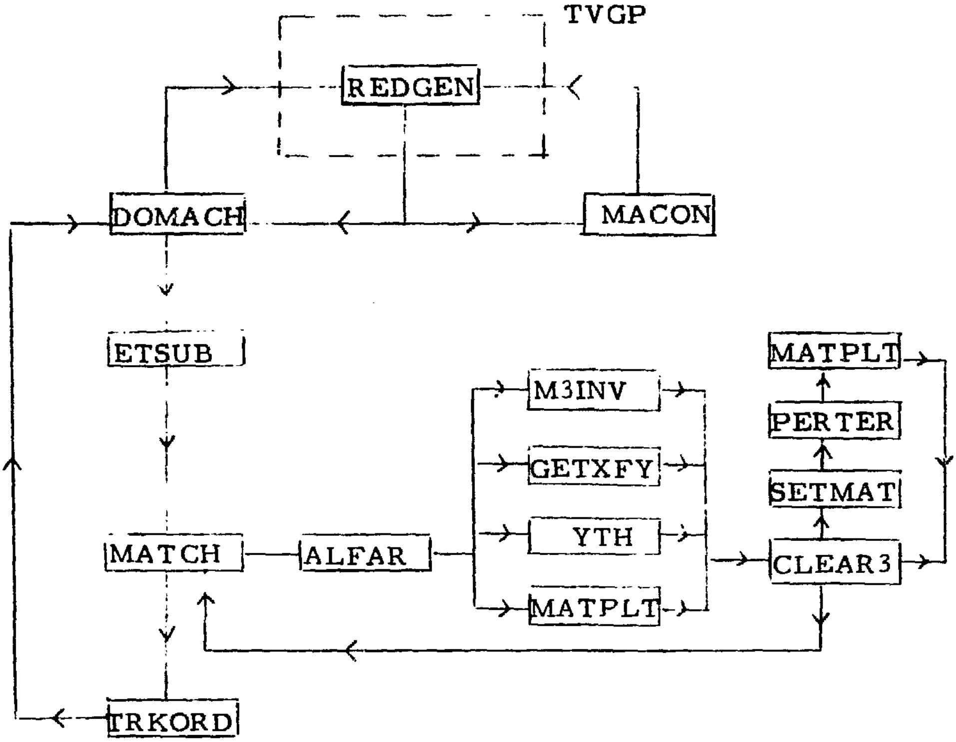
I do not claim that MATCH will be successful for all cases in obtaining a proper match solution. Much depends on the accuracy of the measured points, the optical distortions of the chamber, and the proper set of input match data values. In the case of the K^-p experiment where there are typically 2 or 3 tracks per vertex and two vertices per event, it has proven to be $>$ 95% successful with very few match failures, if any. This is not true in the $\bar{\nu}p$ experiment where high momentum tracks are involved and large numbers of tracks can be produced at an interaction vertex. It has however proven to be very useful in checking solutions for which the tracks have been manually matched. It is not uncommon to find that MATCH has found a different solution than that of the measurer and in most cases the solution it does find is the correct match.

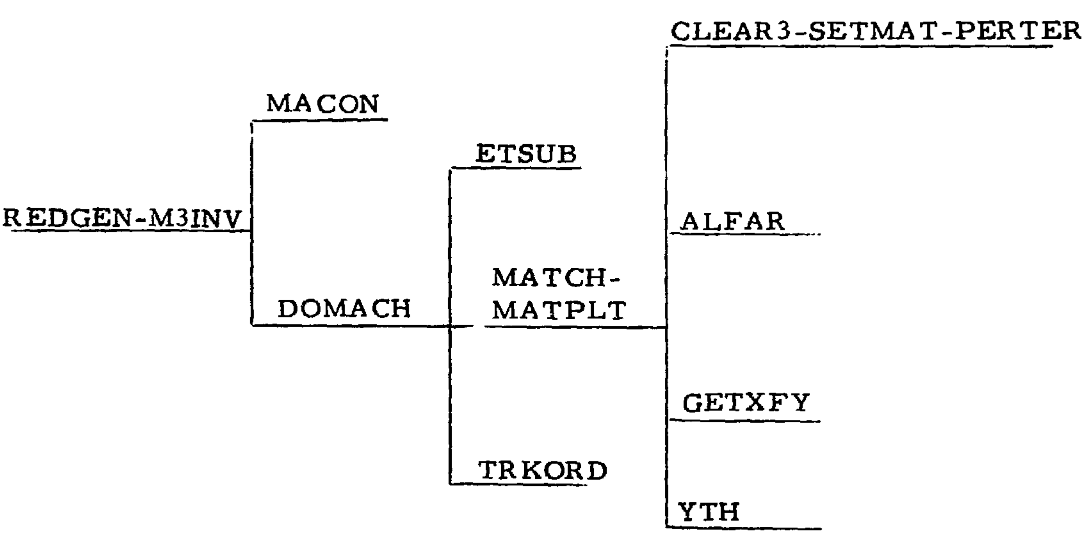
A detailed write-up of each subroutine follows. The reader is advised to first read through the subroutine MATCH to get an overall view of the method of matching which is used and the terminology which is employed in the write-ups of the other routines. Tape copies (9 track or 7 track) will be furnished upon request. Since this package is designed for use by the ANL version of TVGP, the interested user should be familiar with this package and the TVGP routine REDGEN in particular if he wishes to link the current MATCH package to any other existing geometry package. Copies of the ANL 12-foot and 15-foot TVGP programs, including the subroutine REDGEN, can also be furnished upon request.

Table I - SAMPLE MATCH DATA VALUES

Description	$(K^- p)$	$(\bar{\nu} p)$	Parameter Name (see MACON)
Beam ID	KMINUS-P	ANTINEUTRINO	IHOLL
Charge of the beam track	-1	0	ISINBM
Beam momentum (MeV/c)	$(6.5) 10^3$	$(2.0) 10^5$	PBM
Error in beam momentum (MeV/c)	$(2.0) 10^3$	$(5.0) 10^5$	EPBM
Beam Azimuth (radians)	3.14	6.28	AZBM
Error in beam azimuth (radians)	0.30	7.24	EAZBM
Nominal field (kilogauss) negative if pointing into cameras	18.1	25.3	BFIELD
Nominal demagnification	110.	150.	DEMAG
Range of triple estimator for good curvature match	(0.0, 0.0)	$(10^{-12}, 10^{-4})$	(FLIM, FMAX)
Range of triple estimator for good end-point match	$(1.0, 10^{+5})$	(20., 170.)	(TOMIN, TOMAX)
Floating multiplier for acceptable triads	5.0	2.0	CONS
Floating multiplier for number of acceptable ambiguous solutions	1.01	1.10	CRVRAT
Prematched solution	0	3	ISPEC
Forced beam track indicator	0	-1	KBFORC

BLOCK DIAGRAM OF MATCH PACKAGE

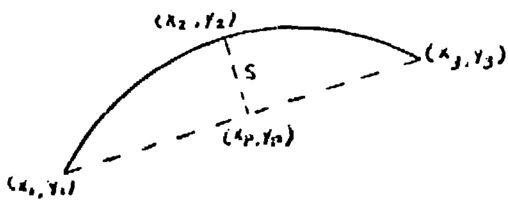




ALFAR

This subroutine is called by MATCH to calculate the track geometry features sagitta, curvature and the angle and tangent of the mid-point. For each measured track in all measured views, ALFAR is entered with the first point, the serial mid-point, and the last point of the track (i. e. X(I), Y(I), I = 1, 2, 3). The coordinates are in the TVGP 'ideal' film plane - 1 cm from the lens, all optical distortions removed.

Sagitta (signed)



$$s^2 = (x_2 - x_p)^2 + (y_2 - y_p)^2$$

The line passing through points (x_1, y_1) and (x_3, y_3) is

$$y_L = mx_L + b_L \quad , \quad m = \frac{(y_3 - y_1)}{(x_3 - x_1)} \quad , \quad b_L = y_1 - mx_1 \quad .$$

The line passing through (x_2, y_2) and (x_p, y_p) is

$$y_\perp = -\frac{1}{m} x_\perp + b_\perp \qquad , \qquad b_\perp = y_2 + \frac{1}{m} x_2 \quad .$$

Solving for x_p, y_p:

$$y_p - mx_p = b_L$$

$$y_p + \frac{1}{m} x_p = b_\perp$$

$$x_p = (b_\perp - b_L)m/(m^2 + 1)$$

$$y_p = m^2 b_\perp + b_L/(m^2 + 1)$$

$$(x_2 - x_p) = -m[(y_2 - y_1) - m(x_2 - x_1)]/(m^2 + 1)$$

$$(y_2 - y_p) = [(y_2 - y_1) - m(x_2 - x_1)]/(m^2 + 1)$$

$$\therefore (x_2 - x_p) = -m(y_2 - y_p) \quad .$$

$$s^2 = (m^2 + 1)(y_2 - y_p)^2$$

$$= (m^2 + 1)[(y_2 - y_1) - m(x_2 - x_1)]^2/(m^2 + 1)^2$$

$$\therefore \quad s^2 = \frac{[(y_2 - y_1)(x_3 - x_1) - (y_3 - y_1)(x_2 - x_1)]^2}{(y_3 - y_1)^2 + (x_3 - x_2)^2} \quad .$$

This can be written in the equivalent form:

$$s^2 = \frac{[(x_2 - x_1)(y_3 - y_2) - (y_2 - y_1)(x_3 - x_2)]^2}{(y_3 - y_1)^2 + (x_3 - x_1)^2}$$

$$s = \frac{(x_2 - x_1)(y_3 - y_2) - (y_2 - y_1)(x_3 - x_2)}{[(y_3 - y_1)^2 + (x_3 - x_1)^2]^{1/2}}$$

$s < 0 \Rightarrow$ Clockwise rotation

$s > 0 \Rightarrow$ Counterclockwise rotation.

The sagitta is defined by multiplying 's' by the sign of the magnetic field (SINFLD).

$\therefore$ Sagitta = SINFLD*s

Curvature

Find the center of the circle generated by the three (x, y) points. Call this center (x_c, y_c). Then the curvature is defined as

$$\text{CURV} = [(x_1 - x_c)^2 + (y_1 - y_c)^2]^{-1/2} \quad .$$

Define:

$$ANUM = (x_2^2 - x_1^2) + (y_2^2 - y_1^2)$$

$$BNUM = (x_3^2 - x_2^2) + (y_3^2 - y_2^2)$$

Then the coordinates (x_c, y_c) are defined by

$$x_c = \frac{(y_3 - y_2)ANUM - (y_2 - y_1)BNUM}{2[(x_2 - x_1)(y_3 - y_2) - (y_2 - y_1)(x_3 - x_2)]}$$

$$y_c = [ANUM/2 - x_c(x_2 - x_1)] / (y_2 - y_1) \quad .$$

Tangent to the track at its mid-point

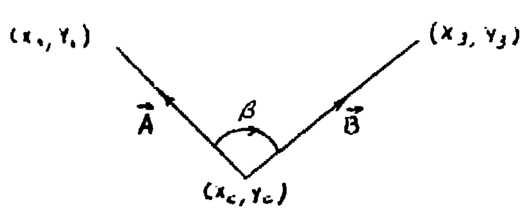
It is assumed that the three (x, y) points fit a circle. Thus, the tangent to the mid-point of the track must be parallel to the chord joining the first and last points. For the purposes of track ordering, we would also like the angle of the tangent to be measured counterclockwise from the positive x-axis.

Define: $SG = \text{sign}\,(y_3 - y_1) \quad .$

The azimuthal angle (ALFA) tangent to the track at its mid-point is thus

$$ALFA = \tan^{-1} ((y_3 - y_1)/(x_3 - x_1)) + (1 - SG)\pi \quad .$$

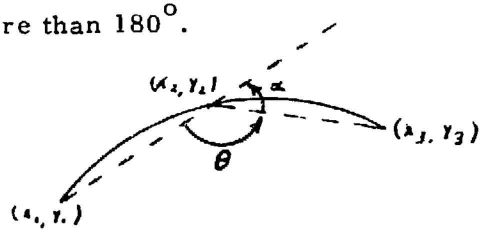
Cosine of the angle of turn of the track



$$\cos\beta = \frac{\vec{A} \cdot \vec{B}}{|\vec{A}|\,|\vec{B}|} = \frac{\vec{A} \cdot \vec{B}}{|\vec{A}|^2} = \vec{A} \cdot \vec{B}\,(CURV)^2$$

$$\therefore \text{ ANGLE} = \cos\beta = [(x_1 - x_c)(x_3 - x_c) + (y_1 - y_c)(y_3 - y_c)] \cdot (\text{CURV})^2 \ .$$

For debugging purposes, we would like to flag a track which has turned through more than 180°.



If the track has turned through more than 180°,

$$\theta < 90^\circ \ , \quad \text{but } \alpha > 90^\circ$$

$$\cos\alpha = -\cos\theta = \frac{(x_3 - x_2)(x_2 - x_1) + (y_3 - y_2)(y_2 - y_1)}{|\vec{12}| \cdot |\vec{23}|}$$

If $\cos\alpha < 0 \Rightarrow \alpha > 180^\circ$ so we set ANGLE = -2.0.

Remarks

For 2-point tracks, sagitta = CURV = ANGLE = 0.0. ALFA and its tangent are calculated using the straight line connecting the points. Note for two-point tracks that the mid-point is taken to be the same as the last point. If a track contains only one point, all parameters are set to zero.

Only the signed sagitta of the track is actually used by the track matching routines when checking charge balance, but the other parameters are useful for ordering the tracks by charge character and provide useful debugging information.

CALLED BY: MATCH
SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED: None
COMMON BLOCKS USED: None

CLEAR3

CLEAR3 is a logic clearing program called by subroutine MATCH to determine the acceptable triads for complete match solutions. There may be more than one, only one, or no solutions possible.

Usage:

CALL CLEAR3(IDEBUG, NVWS, MTFLG, IMF)

Description of parameters:

IDEBUG - Debug print flag set in subroutine MATCH

NVWS - Input number of views (may be 2 or 3)

MTFLG - Output error indicator for the number of acceptable triads used by CLEAR3

- 0 - Number of possible triads in solution set is small enough to be handled by CLEAR3
- 1 - More than 100 possible triads found to be acceptable. Dimensions of array MAL in /MATCOM/ could be exceeded so processing has been terminated.

IMF - Input flag set by subroutine MATCH and used by CLEAR3 for charge balance checking.

Remarks:

1) Debug output is written to logical unit IPRNTU (set in MACON) only if the TVGP print flag IPRNTF=IBCPAR(16) is greater than or equal to 50.

2) For dimensional considerations, only 10 solutions are accepted. If more than 10 solutions are possible, only the 'best' 10 form the solution set.

3) If more than one solution is found, the solution set is ordered so that the last solution is the one which is considered 'best' by CLEAR3.

4) The final solution set is stored in the array NFSOL(J, JV, JSOL)

which is equivalenced to the /MATCOM/ array FUNC.
NFSOL(J, JV, JSOL)=NFSOL(Track No., View No., Solution No.) and has maximum dimensions of (12, 3, 10).
Ex. NFSOL(1, 2, 3)=5 implies that for the third solution, the fifth measured track in view 2 corresponds to the first track of the topology.

Method:

It is assumed that subroutine MATCH has cycled through all possible triples of the measured tracks and stored the appropriate triple estimator in the 3-dimensional array FUNC of /MATCOM/, (i.e. the triple estimator for the triple (I, J, K) appears in FUNC(I, J, K)). First we must ask which of these triples are good candidates for the match solution. An upper limit value (FMAX) has been already constructed by MATCH based on the input data from subroutine MACON. To filter out the best triples (i.e. smallest values) and increase speed, we start with an upper limit estimator value of FMAX4=1/4*FMAX. Cycling through all the views and all the measured tracks, we call subroutine SETMAT to filter out the 'best' triples based on the current FMAX4 value. For each triple accepted by SETMAT, the appropriate measured track numbers are stored in the array MAL(ICNT, I) of /MATCOM/. MAL(ICNT, I)=track number of the measured track in view I for the ICNT accepted triple. Only 100 accepted triples are allowable at any time. If the number of acceptable triples should ever exceed 100, an error condition is noted and CLEAR3 exits with no solution. After constructing the array MAL, we count the number of triples that contain each measured track in each view and store these values in IADD. IADD(I, IND)=total number of acceptable triples which contain track I in view IND. To get at least one match solution, IADD(I, IND) must be greater than or equal to one for all tracks in all views. If IADD(I, IND)=1 for all I and IND values and the number of acceptable triples equals the number of tracks as determined from the topology, the solution must be unique, the NFSOL array is constructed and CLEAR3 exits with one unique solution.

If some measured track in a measured view does not appear in one of the already accepted 'best' triples, the current value of FMAX4 is doubled, and we repeat the cycle calling SETMAT to try to pick up a triple or set of triples containing the measured track. We can only repeat this process until FMAX4=FMAX after which if we have any measured track unaccounted for in the set of 'best' triples, CLEAR3 gives up and returns with no solution. It is possible and quite likely for high momentum experiments that the number of acceptable triples is larger than the expected value as determined from topology, every measured track in all views appear in at least one 'best' triple and could appear in more than one 'best' triple. This leads to ambiguous solutions and CLEAR3 resorts to the construction of a three-dimensional lattice (3 views) or a 2-dimensional grid (2 views) to determine which set of 'best' triple values could logically form a match solution; there may be more than one solution possible. The use of such a 'correlation lattice' follows the ideas set forth by Penny and Burkhard in 1961. As a concrete example, let us study the case of an event having 3 charged tracks measured in 3 different views; a topology code of C2. Let us suppose that CLEAR3 has filtered out these corresponding triples as 'best':

(1, 1, 1) (3, 1, 2) (3, 2, 1) (2, 3, 1) (3, 2, 3) (2, 3, 2) (1, 2, 3)
(3, 3, 3) (1, 3, 3).

These triples are entered as solid dots on the corresponding 3-dimensional cube (correlation lattice). The coordinates of the cube correspond to the number of tracks measured in the respective views. First we ask if there are any planes of the cube which contain a unique point (solid dot). If so, we would immediately remove all points in planes perpendicular to this plane and passing through the unique point since such 'other' points could not possibly form a solution. In our example, there are no such points. Starting with the top plane of the lattice, we pick a starting point and try to construct a logical path down through all the lower planes connecting dots until we form a logical match solution. We do this for all points (dots) on the top plane, being careful to exclude points in lower planes which have already been found to be members of another complete path. The total number of possible complete logic paths which can be formed gives us the total number of match solutions possible and the respective triples which comprise each match solution. In our example, the only logical match solutions obtained are:

1) (1, 1, 1) (2, 3, 2) (3, 2, 3)

2) (1, 2, 3) (2, 3, 1) (3, 1, 2).

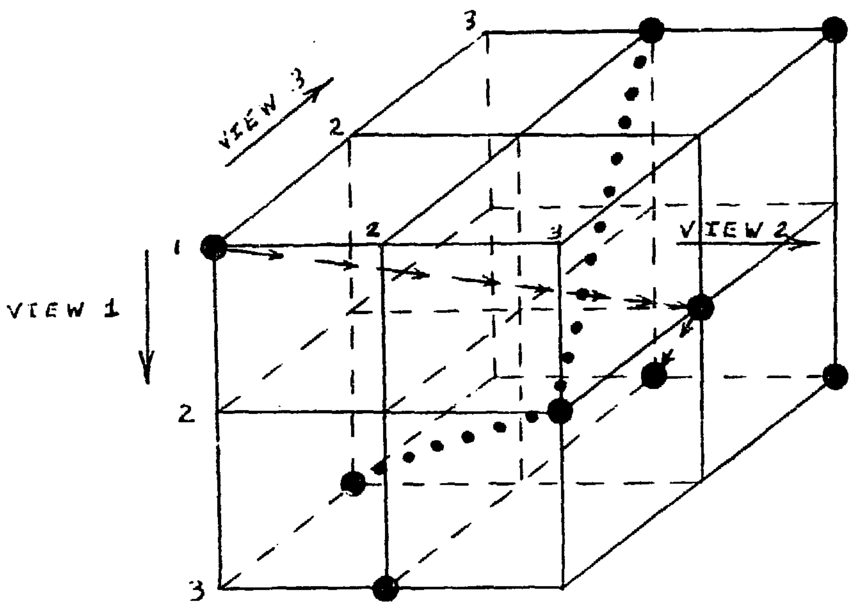
To the right of our cubic lattice is shown the corresponding construction for only two measured views in which case our cube deteriorates to a two-dimensional grid. To each ambiguous solution, we assign an overall estimator or CURFUN value to be used to see if any ambiguous solution can be automatically rejected. If all tracks in all views have definite assignable charge (set in MATCH) but the total charge of the match solution is inconsistent with that for the event, we automatically reject that solution from further consideration. The CURFUN values assigned to each solution are just the average values of the triple estimators for the triples comprising each solution. If more than 10 solutions are possible, we keep only the set of 10 having the smallest CURFUN values. If only one solution is found from the lattice, CLEAR3 exits with one solution. If more than one solution has been found consistent with the charge balance check, we search for the solution having the smallest CURFUN value, 'CURMIN'. If the value is larger than the upper limit estimator value set in subroutine MACON, we accept the solution as 'best' and disregard the others. If we can not automatically disregard any solutions, we follow the following steps:

1) Reorder the solutions so that the last solution is the one with smallest CURFUN value.

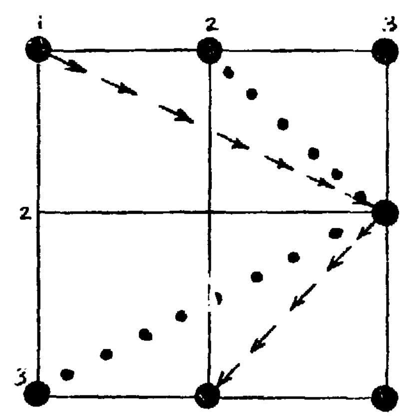
2) Let CURMAX = upper limit estimator value set in MACON. (If CURMAX .LT. 1.0) set CURMIN = LOG_e(CURMIN).

3) For each solution IJ form:

Structure of Solution Lattice



(3 Views)



(2 Views)

LOGICAL PATHS

1) (1, 1, 1)--(2, 3, 2)--(3, 2, 3)

2) (1, 2, 3)--(2, 3, 1)--(3, 1, 2)

$$\text{RATIO}=\text{CURFUN(IJ)/CURMIN} \qquad \text{(CURMAX.GE.1.0)}$$

$$=\text{CURMIN}/\text{LOG}_e(\text{CURFUN(IJ)}) \qquad \text{(CURMAX.LT.1.0)}$$

If RATIO is less than 0 or greater than the parameter CRVRAT (set in MACON), we disregard solution IJ. (In essence we disregard all solutions which are more than CRVRAT times the minimum CURFUN found.) The remaining 'filtered' solutions then comprise the final match solution set and CLEAR3 is exited.

CALLED BY: MATCH
SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED: SETMAT, MATPLT
COMMON BLOCKS USED: /MATHST/, /MATCHL/, /MATCOM/

References:

1) S. J. Penny and J. H. Burkhard - Multidimensional Correlation Lattices as an Aid to Three-Dimensional Pattern Recognition - AFIPS Conf. Proc., Vol. 28 (1961), Spring Joint Comp. Conf., p. 449.

2) S. W. Golomb and L. D. Baumert - Backtrack Programming - JACM, Vol. 12, No. 4 (October 1965), pp. 516-524.

3) W. Manner - Track Matching in Bubble Chamber Geometry Programs - POLLY Note 18 - High Energy Physics Div., Argonne National Laboratory (March 1968).

4) R. G. Glasser - ANL Match Program Short Description - High Energy Physics Division, Argonne National Laboratory (June 29, 1972), (Divisional report - unpublished).

DOMACH

DOMACH is the main driver routine for the match package. It sets up the variables to be used by MATCH, performs the necessary bookkeeping of the solutions returned by MATCH per vertex and readjusts pointers in the input record so that TVGP can assume that the tracks in each view have been ordered properly to reflect the correct MATCH solution. DOMACH is called by the TVGP routine REDGEN and according to an input/output flag (MAMBIG) will either process a new event through MATCH or pick up another ambiguous solution of the same event for TVGP to process.

Usage:

Call DOMACH (MAMBIG)

Parameters:

MAMBIG - Input/output flag directing the logic flow of DOMACH. On the initial call to DOMACH, MAMBIG must be equal to zero. For all subsequent calls to DOMACH, MAMBIG becomes an input variable set by the previous call to DOMACH.

MAMBIG	= 0	Tells DOMACH to begin matching for a new event.
	= J(J $\neq$ 0)	Tells DOMACH to do the necessary bookkeeping for solution J of a previously matched event. (Note: An event can have as many as 10 match solutions, thus J can run from 1 to 9.)

On output from DOMACH, the value of MAMBIG tells you how many more solutions are left from the solution set for the current event to be processed through TVGP.

Remarks:

1) The success of the match package is noted by the variable IFAIL

in blank common.

IFAIL = 0 A solution set has been found.

200 No match possible.

205 Either one of the missing views was negative or there were two missing views and the user chose not to process two-view events.

206 Too many acceptable triads for the match routines to handle. (See CLEAR3.)

2) Debug printout is written to logical unit 3.

3) Dimensional considerations restrict an event to a maximum of 12 tracks/vertex, 20 tracks/event, and 3 measured views.

Method:

Since DOMACH is primarily a bookkeeping program, the order of steps taken is rather simply structured. Let us first suppose DOMACH is entered for a new event. The following steps are taken:

1) Find the number of views and save all pointers to the tracks in each view.

2) Call the user routine ETSUB to get the number of vertices, the number of tracks/vertex and the total charge/vertex.

3) Cycling over the vertices:

   a) Call MATCH to get a match solution at the current vertex. If there is no match at any one vertex, set IFAIL parameter and return.

   b) Call TRKORD to order the tracks of the current vertex by charge.

   c) If the current vertex is not the first, do the necessary bookkeeping to the NTSL array (event solution array) to include the solutions at the current vertex.

   d) Set JSOL to the maximum number of solutions found for the event.

4) Bump the MAMBIG value by -1.

5) Reorder the track location pointers in the input record to reflect the match solution JSOL and return.

If DOMACH is entered with MAMBIG equal to N (N. NE. 0), set JSOL to MAMBIG and go directly to step 4).

<u>CALLED BY:</u> REDGEN (TVGP routine)

<u>SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED:</u> ETSUB, MATCH, TRKORD

<u>COMMON BLOCKS USED:</u> BLANK COMMON (TVGP)
/ANLIN/
/MATCOM/
/DOMACH/

ETSUB

ETSUB is not properly a member of the MATCH subroutine package. It is a user-supplied subroutine which for the current event calculates the number of vertices, the number of expected tracks/vertex and the total charge/vertex.

Usage:

CALL ETSUB (NVTXS, NVTXT)

Parameters:

NVTXS	- Number of vertices. (If there is no beam track for this event, set NVTXS negative.)
NVTXT(I, 1)	- The number of tracks at vertex I.
NVTXT(I, 2)	- The total charge at vertex I.

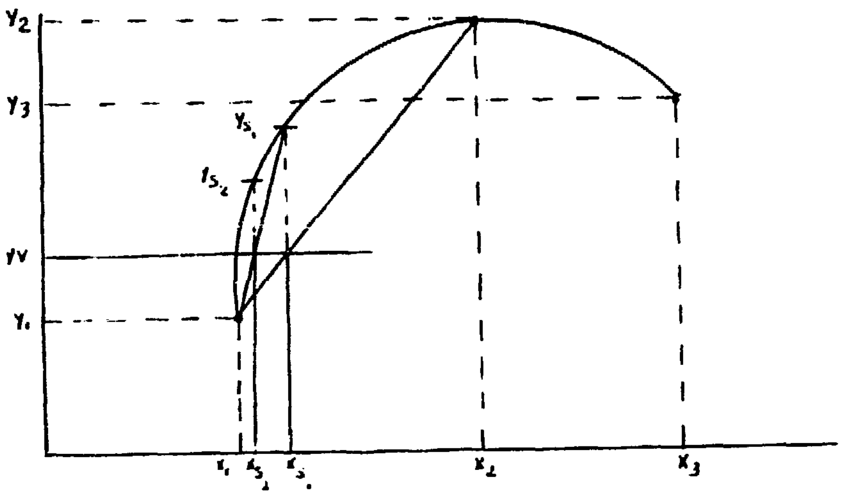
Remarks:

1) NVTXT must be dimensioned to NVTXT(7, 2).
2) ETSUB is called once per event by DOMACH.
3) All the necessary information can be decoded from the Palmer Code contained in words 44-48 of the array IN in the labelled common block /ANLIN/. (See Appendix.)

CALLED BY: DOMACH

GETXFY

Given three points on a track (X(I), Y(I) I = 1, 2, 3) and a y-value (YV) of a point such that $Y(1) < YV < Y(2)$, the corresponding x-value (XV) of the point is determined through iterative use of linear inverse and Lagrange interpolation.



Suppose the input points (X(I), Y(I) I = 1, 2, 3) and YV are as shown in the diagram. The first step (S_1) is to construct X_{S_1} by linear inverse interpolation.

$$X_S = X_1 + (Y_1 - YV)(X_2 - X_1)/(Y_1 - Y_2) \quad .$$

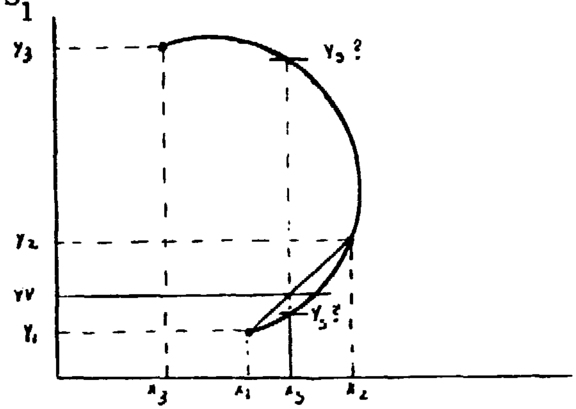
Then we use Lagrange interpolation to find the corresponding Y_S point and check to see if it equals YV. Note that this is essentially a cubic fit to the curve.

$$Y_S = \frac{(X_S - X_2)(X_S - X_3)}{(X_1 - X_2)(X_1 - X_3)} Y_1 + \frac{(X_S - X_1)(X_S - X_3)}{(X_2 - X_1)(X_2 - X_3)} Y_2 + \frac{(X_S - X_1)(X_S - X_2)}{(X_3 - X_1)(X_3 - X_2)} Y_3 \quad .$$

If the relative error in Y_S is greater than 0.1%, we iterate the process after first changing the order of the three reference points.

$Y_S > YV$	$Y_S < YV$
$(X_1, Y_1) \rightarrow (X_1, Y_1)$	$(X_S, Y_S) \rightarrow (X_1, Y_1)$
$(X_S, Y_S) \rightarrow (X_2, Y_2)$	$(X_2, Y_2) \rightarrow (X_2, Y_2)$
$(X_2, Y_2) \rightarrow (X_3, Y_3)$	$(X_3, Y_3) \rightarrow (X_3, Y_3)$

Up to ten iterations are allowed. If no convergence is obtained after ten iterations, the last X_S value found is chosen as XV. The program is sufficiently flexible to handle the case where points X_1 and X_3 are interchanged (i. e. a YV value near the end of a track). If the curvature is so large that two Y_S values are possible (see diagram below), then the program exits with the value of X_{S_1}.



If for any reason, GETXFY experiences difficulties (i. e. Y_S or X_S fall out of range, multi Y_S values possible, or input points illogical), the program exits and MATCH performs strict linear inverse interpolation only.

<u>CALLED BY:</u> MATCH
<u>SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED:</u> None
<u>COMMON BLOCKS USED:</u> /MATC M/

MACON

Subroutine MACON reads in all necessary constants if matching is to be done and calculates the projected beam curvature and its error on the TVGP film plane if matching is to be done.

Usage:

CALL MACON (IMTGO)

Parameters:

IMTGO - Output flag indicating whether matching is to be done.
 1 → Match all events.
 -1 → No matching is to be done.

Remarks:

MACON is called only once by the TVGP routine REDGEN. MACON reads from logical unit 5 two cards defining all the necessary match constants. The initial debug print unit is set to 3 but can be overwritten by the second match card. If an end-of-file is read on the first card, IMTGO is set to -1 and no matching is to be done.

DATA CARD 1

FORMAT (3A4, 2X, I2, I3, 6F10.4)

CONTENTS

IHOLL(1-3)	Three 4-character words to define the beam.
IPRNTU	Match debug print unit.
ISINBM	Charge of the beam track.
PBM	Beam momentum (MeV/c).
EPBM	Error in beam momentum (MeV/c).
AZBM	Beam azimuth (radians).

EAZBM	Error in beam azimuth (radians).
BFIELD	Nominal field (kilogauss), negative if pointing into cameras.
DEMAG	Nominal demagnfication used to calculate the projected curvature of the beam on the TVGP film plane.

DATA CARD 2

FORMAT (6E10.3, 14X, 3I2)

CONTENTS

CRVRAT	For ambiguous match solutions, let EMIN be the minimum mean triple estimator of all solutions. Those solutions whose mean triple estimator is .GT. CRVRAT*EMIN are rejected as bad match solutions.
FLIM FMAX CONS	For three-view triples, all triple estimators less than FLIM are accepted and all estimators greater than FMAX are rejected. CONS is a constant multiplier which effects the number of possible triples accepted as match candidates. Larger CONS values imply more accepted triples. (Normally 1.0 ≤ CONS ≤ 2.5.) (If curvature match is not desired, set FLIM=FMAX=0.0.)
TOMIN TOMAX	Minimum and maximum range values for the end-point matching of tracks. (If end-point matching is not desirable, set TOMIN=TOMAX=0.0.)
ICHMBR	Parameter defining chamber 12 -- 12-foot ANL chamber 15 -- 15-foot FNAL chamber.
ISPEC	Debug parameter useful for checking already 'prematched' solutions. 0 - Has no effect on match solutions. 1 - If the match solutions do not contain the 'prematched' solution, this solution is added to the match solution set before exiting from MATCH.

('Prematched' solution is the order of the tracks as they appear in the track banks of the input record.)
2 - Same as ISPEC=1 but only for 2-view events.
3 - No match solution → same as ISPEC=1. Match solution found → same as ISPEC=2.

KBFORC — Beam track flag
0 - Do not force any track to be the beam track.
-1 - Force the first track of the first vertex in each view to be the beam track.
-2 - Force the last track of the first vertex in each view to be the beam track.

Calculated quantities:

Sign of field

SINFLD = sign(1., BFIELD)

Projected curvature of beam on TVGP film plane

CPBM = 0.3 * ABS(BFIELD) * DEMAG/PBM

Error in projected curvature

EPBM = CPBM * EPBM/PBM

EPBM is stored in the variable PBM before exiting MACON.

CALLED BY: REDGEN (TVGP routine)
SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED: None
COMMON BLOCKS USED: /MATCOM/

MATCH

Subroutine MATCH attempts to find all possible matches at a vertex of the measured tracks in two or three views.

Usage:

CALL MATCH (IVTXX, NVWS, IFAIL, ISTOP)

Parameters:

IVTXX - Vertex number of current vertex.

NVWS - Number of views.

IFAIL - Flag indicating status of MATCH routine.
0 - A MATCH solution has been found.
205 - One of the missing views is negative, or the number of measured views is less than two or greater than three.
206 - Too many acceptable triads for MATCH to handle. A solution set cannot be formed.

ISTOP - ISTOP(12, 3) is an input array designating the stopping quality of the tracks in each view.
ISTOP(I, J) = 0 Track I in View J is not a stopper.
ISTOP(I, J) = 256 Track I in View J is a stopping track.

Remarks:

1) MATCH is called by the subroutine DOMACH for each vertex of the current event.

2) Full debug printout is written to logical unit IPRNTU (set in MACON) if the TVGP print flag (IPRNTF = IBCPAR(16)) is .GE. 10. If IPRNTF is .GE. 50, full debug printout from the logic handler CLEAR3 is produced as well. (NOTE: Full debug printout is excessive and should only be used in the determination of the constants needed to determine the acceptable triads.)

3) MATCH assumes that the same number of tracks at the current vertex have been measured in each of the views. Some attempt is made

to work with differing numbers of tracks, but the routine is not written in general to handle this facility.

4) Definitions:

Triple (or triad) -	Any combination of 3 tracks taken one from each view. For two-view tracks, the third member of the triple is carried as a dummy track.
Estimator (or FUNC value) -	A number assigned to every possible triad indicating how well these tracks match.
Solution set -	The set of triads comprising the match solution. There may be one member of the set implying a unique solution, more than one member of the set implying ambiguous solutions, or no member of the set implying no solution.

5) Two-view events will be matched assuming the end-points of the tracks in one view have corresponding end-points in the other view. If two-view events are not to be processed, set TOMIN=TOMAX=0.0 in labelled common /MATCHL/.

6) Matching is done in the 'ideal' TVGP film plane - 1 cm from the lenses with 'all optical distortions removed'. The (x, y) coordinates of the track in this coordinate system appear in the array PTSV of the labelled common block /ANLIN/.

7) Every experiment will require a new set of MATCH constants to obtain the best match solutions for every event. It is advised that full debug printout be used in the early stages only to ascertain the order of these unknown constants.

Method:

The current version of MATCH follows very closely the methods outlined in Refs. 1), 2), and 8). I will first give a general overview of the program and then go into specifics.

Each track of the vertex leaves its own characteristic path of bubbles in the bubble chamber. The method of handling the rays from corresponding points in different views is done in either of two ways or a combination of both depending upon the number of views measured and to some extent the desire of the user. The two methods employed are called:

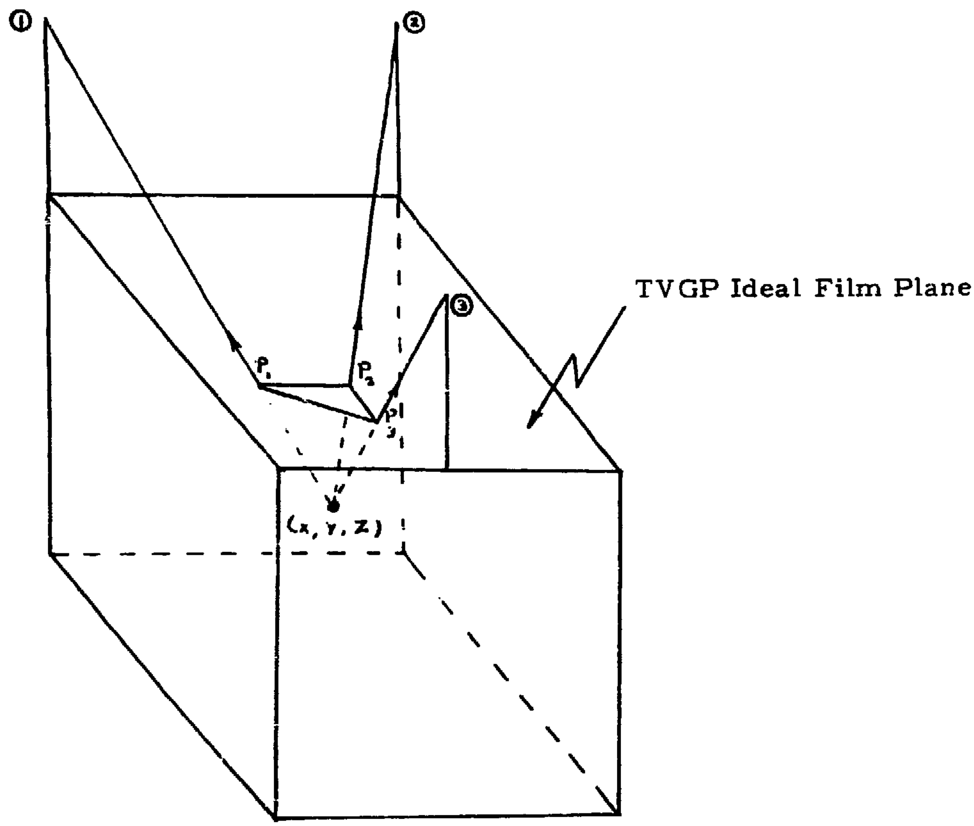
A) END-POINT MATCH

B) CURVATURE MATCH.

End-point matching as the name implies uses only the end-points of the measured tracks to assign an estimator value for the possible triples. Curvature match uses the full range of points on all tracks to obtain an estimator value for each triple. Since this method uses all track points and as such completely follows the trajectory of the tracks, we designate it as the 'curvature' match. Let us examine a track bubble in the chamber and its rays to each of the view cameras. As in the accompanying diagram, the rays intersect the TVGP 'ideal' film plane at what we term 'corresponding' points.

A) END-POINT MATCH

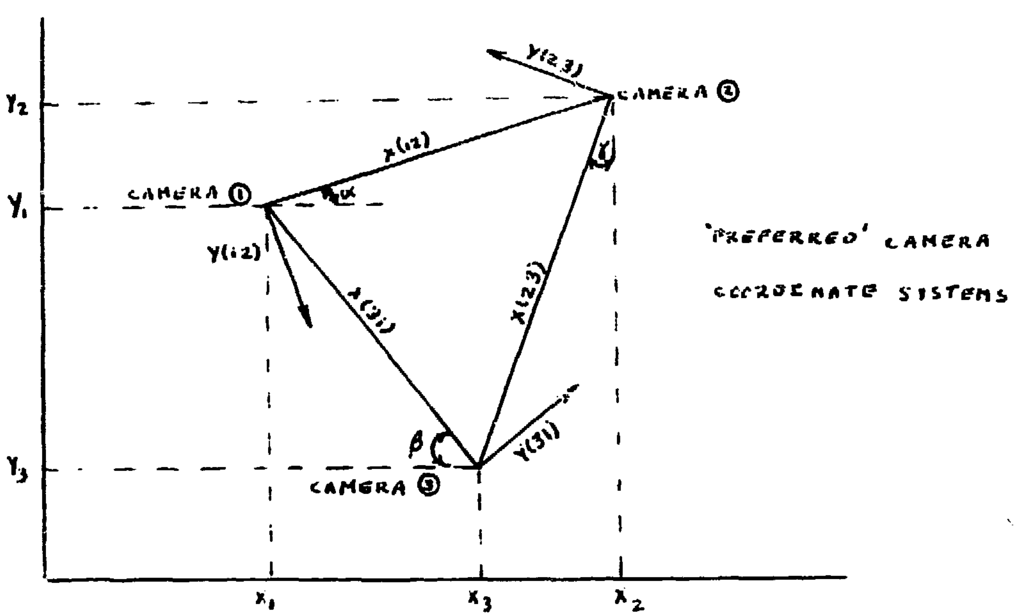
In the END-POINT match, we use only the last point of each measured track and assume them to be the definite end-points of the tracks. The tracks will have a definite end-point if, for instance, they enter the walls or bottom of the chamber, clearly form another interaction or are stopping tracks. Even if the tracks go out the top of the chamber or the last point of the tracks is not a well-defined end-point, the END-POINT facility may still find a unique match. (In such cases, the probability of obtaining a unique match is inversely proportional to the total number of tracks in the event.) For each triple of tracks, we first calculate a space point which is the closest point of approach of the rays from the ideal film plane points in each of the possible view pairs. NOTE: The use of pairs of views implies that END-POINT match can be used to effectively handle the case of only two measured views. For two views, there is only one possible view pair. For three views, there are three possible


①
②
③
P_1
P_2
P_3
(x, y, z)
TVGP Ideal Film Plane

view pairs. After calculating the initial space point for a particular view pair, we project the space point back into the various film coordinate systems and compare these values to those calculated by the TVGP routine FIDO from the input track data point values. A chi-square estimator is then formed for this view pair and set to be the triple estimator for that triple of tracks. For three views, we choose the triple estimator to be the maximum chi-square value of the three two-view combinations. Note that in the case of three measured views, we could just as easily have used all three corresponding points to approximate the space point and thus eliminate the need for view pairs. However, if two tracks of the triple are correct but one is wrong, the constraints of the fit to the space point are such as to minimize the effects of the incorrect track and useful information is lost. If the three tracks of the triple are indeed a correct match, then the chi-square value for each view pair should be approximately equal, thus the decision was made to choose the maximum value to represent an estimator for the triple. In the case of a triple comprised of two correct tracks and one bad track, the view pairs involving the bad track will give chi-square values several orders of magnitude larger than the view pair involving the correct tracks. The technique employed here is based on the similar approach of the ANL subroutine LSVERT in TVGP. Reference 8) contains a complete description of the optical assumptions employed and the method of obtaining the intial space point and projecting it back into the film coordinate systems.

B) CURVATURE MATCH

Let us look again at our track bubble in the chamber. The optical rays from the bubble to each of the three camera lenses will intersect the 'ideal' film plane at particular points. These three points of intersection form a triangle which is similar to the triangle formed by the cameras. The similarity of the triangles implies that the internal angles of the triangle joining the cameras and that the ratios of corresponding sides in the triangles must be equal. Since we must have three points to uniquely determine the triangle in the 'ideal' film plane, CURVATURE match can only be used for events measured in <u>three</u> views. Suppose we have a triple of tracks measured in three views. How do we form an estimator for the triple? Let us start by choosing the track in View 1 as our reference or 'best' track. Starting with the second measured point of this track, we ask for its corresponding points on the tracks in Views 2 and 3. The true corresponding points in Views 2 and 3 will not in general be any of the measured track points in these views, so we construct three 'preferred' coordinate systems, the (12) system, the (23) system and the (31) system such that if we rotate the tracks of view I and J into the (IJ) 'preferred' system, the corresponding points on the tracks will have the same y-coordinate value. This is easily accomplished if we orient the x-axis of the preferred (IJ) system to lie along the line joining the cameras in Views I and J. The coordinate systems are as pictured below.



The rotations involved are fully described by the accompanying set of equations.

ROTATIONS AND REFLECTIONS

Define: $\hat{x} = -x$, $\hat{y} = -y$

(12) COORDINATE SYSTEM

$$x(12) = x \cos\alpha + y \sin\alpha$$

$$y(12) = -x \sin\alpha + y \cos\alpha$$

$$x(12) = \frac{x(-\hat{x}_2 + \hat{x}_1)}{|\vec{12}|} + \frac{y(-\hat{y}_2 + \hat{y}_1)}{|\vec{12}|}$$

$$y(12) = \frac{-x(-\hat{y}_2 + \hat{y}_1)}{|\vec{12}|} + \frac{y(-\hat{x}_2 + \hat{x}_1)}{|\vec{12}|}$$

Reflect in y(12)

$$y(12) = \frac{x(\hat{y}_1 - \hat{y}_2)}{|\vec{12}|} - \frac{y(\hat{x}_1 - \hat{x}_2)}{|\vec{12}|}$$

$$x(12) = x \cdot RMAT(1, 1, 3) + y \cdot RMAT(2, 1, 3)$$

$$y(12) = x \cdot RMAT(2, 1, 3) + y \cdot RMAT(2, 2, 3)$$

(31) COORDINATE SYSTEM

$$x(31) = x \cos(\pi - \beta) + y \sin(\pi - \beta)$$

$$y(31) = -x \sin(\pi - \beta) + y \cos(\pi - \beta)$$

$$x(31) = \frac{x(\hat{x}_3 - \hat{x}_1)}{|\vec{13}|} + \frac{y(\hat{y}_3 - \hat{y}_1)}{|\vec{13}|}$$

$$y(31) = \frac{x(\hat{y}_3 - \hat{y}_1)}{|\vec{13}|} - \frac{y(\hat{x}_3 - \hat{x}_1)}{|\vec{13}|}$$

$x(31) \quad x \cdot RMAT(1,1,2) + y \cdot RMAT(2,1,2)$

$y(31) \quad x \cdot RMAT(2,1,2) + y \cdot RMAT(2,2,2)$

(23) COORDINATE SYSTEM

$$x(23) = x \cos\rho + y \sin\rho \qquad (\rho = 3\pi/2 - \gamma)$$
$$y(23) = -x \sin\rho + y \cos\rho$$

$$x(23) = \frac{x(-\hat{x}_3 + \hat{x}_2)}{|\vec{23}|} + \frac{y(-\hat{y}_3 + \hat{y}_2)}{|\vec{23}|}$$

$$y(23) = \frac{x(\hat{y}_2 - \hat{y}_3)}{|\vec{23}|} - \frac{y(\hat{x}_2 - \hat{x}_3)}{|\vec{23}|}$$

$x(23) = x \cdot RMAT(1,1,1) + y \cdot RMAT(2,1,1)$

$y(23) = x \cdot RMAT(2,1,1) + y \cdot RMAT(2,2,1)$

ARRAYS USED IN MATCH FOR ROTATIONS

PCAM(1, I) = minus the space x-coordinate of the camera in measured View I.

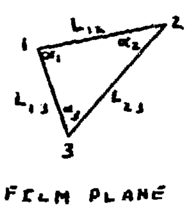
PCAM(2, I) = minus the space y-coordinate of the camera in measured View I.

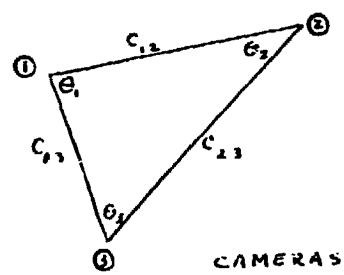
$FACT(1) = 1/|\vec{23}|^2$

$FACT(2) = 1/|\vec{13}|^2$

$FACT(3) = 1/|\vec{12}|^2$

Let us return to our reference track in View 1. To find its corresponding point in View 2, we rotate both tracks into the (12) coordinate system. Now for the second point of the reference track in View 1, we know the corresponding point in View 2 will have the same y-coordinate value. We search the points of the track in View 2 until we find a pair of measured track points whose y-values include the desired y-value of the point in View 1. Using these two points in View 2 and the next consecutive track point in View 2, we ask the subroutine GETXFY to give us the x-value of the corresponding track point in View 2. GETXFY uses inverse linear and Lagrange interpolation to accomplish this. Strict linear inverse interpolation is not used because of the increased optical distortion effects of the 12-foot and 15-foot chambers. After finding the corresponding point in View 2, we repeat the process for the tracks in Views 1 and 3, this time using the (31) coordinate system. Now we undo the rotations and obtain the corresponding points in the 'ideal' film plane. These three points now form a triangle in the 'ideal' film plane and an estimator is attached to this triple indicating its degree of similarity to the triangle formed by the cameras. Suppose the film plane triangle and the camera triangle are as pictured below:





Define:

$$RT1 = \left|\alpha_1/\theta_1 + \theta_1/\alpha_1 + \alpha_2/\theta_2 + \theta_2/\alpha_2 + \alpha_3/\theta_3 + \theta_3/\alpha_3 - 6.0\right|$$

$$RT2 = \left|L_{12}/C_{12} + C_{12}/L_{12} + L_{23}/C_{23} + C_{23}/L_{23} + L_{13}/C_{13} + C_{13}/L_{13} - 6.0\right|$$

$$RT = (RT1 + RT2)^2$$

The value RT represents our degree of similarity for the measured point in View 1. Now we cycle over all points of our reference track up to but not including the last point and for each point construct an RT value. A chi-square value for our reference track in View K is now formed as

$$\chi_K^2 = \frac{\sum_{I=1}^{N} (RT)_I * (PL)_I}{\sum_{I=1}^{N} (PL)_I}$$

(N = number of points on the reference track for which corresponding points have been found.)

The weight factor $(PL)_I$ equals the length of the track from the first measured point to point I. This is done so that reference points close to the beginning of the track will carry considerably less weight since in almost all cases they will have definite corresponding points in the other tracks.

Because of bad stereo effects and/or optical distortions, we must cycle over each track of the triple using each as our reference track. In this way, we obtain three χ^2 values for each triple. In general, the smallest χ^2 value becomes the estimator for the triple with the following restrictions.

1) If for any reference track K the value of N in the expression for χ^2_K is equal to 1 and that reference track has more than 3 points, we flag the triple as 'bad'.

2) If for any reference track K the value of N equals zero, we flag the triple as 'bad'.

Triples flagged as 'bad' cannot be considered as part of a match solution. If all tracks of the triple contain only two points, the CURVATURE match will have obvious problems, so MATCH forces the triple estimator for this case to be 'good' and leaves it to the logic handler CLEAR3 to decide if this triple is really a good match possibility.

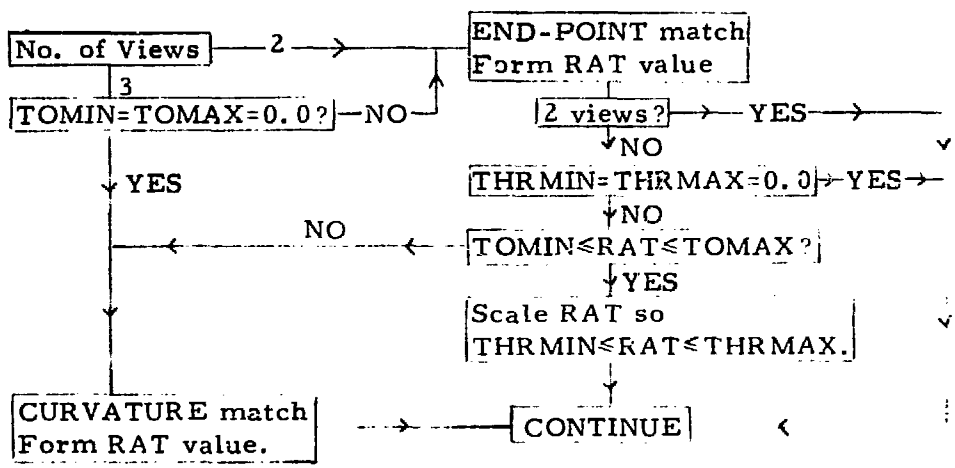
For high momentum tracks, the usefulness of CURVATURE matching is not so obvious since there is very little real curvature information and the tracks will in all probability be very close to each other in space. Can we effectively use the END-POINT match and combine it with the CURVATURE match if necessary? The answer is YES. MATCH allows for the usage of either END-POINT or CURVATURE match or a combination of both. Let us make the following definitions:

RAT = triple estimator value calculated by either END-POINT or CURVATURE matching.

TOMIN, TOMAX   lower and upper values for expected 'good' triples from an END-POINT match (see MACON)

THRMIN, THRMAX = lower and upper values for expected 'good' triples from CURVATURE match (see MACON).

Then the logic flow of determining the appropriate match facility to be used is as shown below:



Once we form triple estimators for all possible triples of tracks, we call subroutine CLEAR? to logically determine which set of triples comprise a match solution.

Specifics of MATCH Routine

1) See if there is more than one track in each view. If not, the solution is unique and we return.

2) Loop over all tracks in all views and calculate the total charge/view, the number of tracks/view, and the number of unsigned tracks/view.

3) Looping over tracks and views, check for charge balance. Tracks may be assigned ambiguous charge if their sagitta is less than the value SAG set in DOMACH or if an assignment of ambiguous charge is necessary to obtain charge balance.

4) Calculate the intrinsic angles of the triangle formed by the camera lenses and set up the proper rotation coefficients to be used later in obtaining

the triple estimators for CURVATURE match only.

5) Zero out the triad estimators (FUNC values).

6) Loop over all possible track combinations to form triples of tracks (one track from each view). This loop can be performed a maximum of 3 times.

For each triple:

a) If no track of the triple is a stopping track or all tracks of the triple are stopping tracks, then go to b). Otherwise, flag the triple as bad ($RAT=10^5 \cdot FMAX$) and go to 7).

b) If this is not the first vertex of the event, continue processing. If it is and we know that the first or last track has already been prematched (as indicated by KBFORC = -1 or -2), we flag the correct triple as good ($RAT=10^{-40}$) and all other triples which contain these tracks as bad ($RAT= 10^5 \cdot FMAX$). We then go to 7).

c) If this is the first time we are forming triple estimators, we only look at triples for which charge balances. If this is the second time we are forming triple estimators, we ignore charge balance. If this is the third time we are forming triple estimators, we go directly to 7) after multiplying the maximum triple estimator value (FMAX) by 10.0.

d) If all tracks of the triple are 2-point tracks, we set $RAT=10^{-20}$ and go to 7).

e) For each triple we use either the END-POINT MATCH or the CURVATURE match or both to obtain a triple estimator.

7) We store the estimator (RAT value) for the triple in the 3-dimensional array FUNC having first cleared the last three bits of RAT since these bits are used by subroutine CLEAR3.

8) After looping over all possible triples, we call subroutine CLEAR3 to get a match solution. If we do not get a solution on the first call to CLEAR3, we go back to step 7) and try again ignoring charge balance. If after the second call to CLEAR3 we do not get a solution, we go back to step 7) and try a last time after increasing the FMAX value. If we still do not get a solution, we

exit with the number of solutions (NTSL) equal to zero. If we do not get a match solution set, we see if the user has set the ISPEC option (see subroutine MACON) and proceed accordingly before exiting.

CALLED BY: DOMACH

SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED: ALFAR, CLEAR3, GETXFY, YTH, MATPLT, M3INV, AND(X, Y).

Note: AND(X, Y) performs a logical AND of X and Y. This is an intrinsic function for the IBM-FORTRANH compiler only.

COMMON BLOCKS USED:		
	BLANK COMMON	(TVGP)
	/OPTC12/	(TVGP)
	/MATHST/	
	/MATCHL/	
	/MATCOM/	
	/ANLIN/	(TVGP)
	/DOMACH/	

References:

1) V. Pless - 'A Proposed Solution to the MATCH Problem' - ANL-7346, Argonne National Laboratory - June 1967.

2) P. L. Bastien, J. N. Snyder and V. Pless - 'A Track Matching Program for Bubble Chamber Photographs' - Comp. Phys. Comm., 2 (1971), pp. 394-419.

3) C. Grosso, G. Rinaudo and A. E. Werbrouch - 'Computer Track Matching in Bubble Chambers' - Nucl. Instru. and Methods 48 (1967) pp. 71-76.

4) R. G. Glasser - 'ANL Match Program Short Description' - Argonne National Laboratory - High Energy Physics Division (unpublished) - June 1972.

5) W. Manner - 'Track Matching in Bubble Chamber Geometry Programs' - POLLY Note No. 18, Argonne National Laboratory - High Energy Physics Division - March 1968.

6) A. D. Bryden - 'Computer Programs for Matching Images from Three Views in a Bubble Chamber' - RHELR-235 - January 1972, p. 35.

7) T. Day, A. Johnson, and F. Solmitz, TVGP, Alvarez Group Programming Note, P-117 (unpublished).

8) G. F. Gieraltowski - 'Film Setting Error Parameters in TVGP and the Two Point Reconstruction Program - LSVERT' - High Energy Physics Div. - Programming Note No. 48 - Argonne National Laboratory - October 1975.

MATPLT

This is a dummy routine whose purpose is to histogram the triple estimators created by the MATCH routine. It is left as a dummy routine so that the user can load in his own histogramming package at load time. The triple estimator value and histogram indicator number are stored in the labelled common block /MATHST/ (see Appendix).

Subroutine MATPLT is designed to be a useful tool for debugging and for setting the appropriate match constants correctly. An ENTRY point 'FINISH' is included so the user can properly close out his histogramming package after the last event has been processed by TVGP. (It is left to the user to place the appropriate call to FINISH in GPWRIT or RDANL.)

CALLED BY: MATCH, CLEAR3
SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED: None
COMMON BLOCKS USED: /MATHST/ (see Appendix).

M3INV

Calculate the inverse of a 3 x 3 symmetric matrix.

Usage:

```
CALL M3INV (A, DET)
```

The 3 x 3 matrix to be inverted is stored in the array A in the following form

$$\begin{pmatrix} A_1 & A_2 & A_3 \\ . & A_4 & A_5 \\ . & . & A_6 \end{pmatrix}$$

The determinant of the matrix is stored in DET. The inverse is calculated in place so on output, A contains the inverse of the desired matrix.

CALLED BY: MATCH, LSVRT(in TVGP)
SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED: None
COMMON BLOCKS USED: None

PERTER

This subroutine performs a logical permutation of three input variables.

Usage:

CALL PERTER (N, I, J, K, IN, JN, KN)

Description of parameters:

N	- Position in output list where the first variable is to be stored. (1. LE. N. LE. 3)
I, J, K	- The three input variables to be permuted.
IN, JN, KN	- Output variables into which I, J, K are stored.

The value of N determines the order of the permutation. The permutation is then performed cyclically.

CALLED BY: SETMAT
SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED: None
COMMON BLOCKS USED: None

SETMAT

SETMAT is the basic filtering program called by subroutine CLEAR3. Based on the triple estimator values, it determines which triples are acceptable as match candidates.

Usage:

CALL SETMAT (IND, I, NVWS, IMF, EFMAX)

Description of parameters:

IND - Input view to be held constant in the search for acceptable triples.

I - Track number of track in view IND to be held constant in the search for acceptable triples.

NVWS - Number of views

IMF - Input flag set by subroutine MATCH and passed by subroutine CLEAR3. The upper limit for the estimators of acceptable triples is determined differently by SETMAT based on the value of IMF.

EFMAX - Output variable equal to the upper limit for acceptable triples having track I in view IND.

Remarks:

1) SETMAT is called only by subroutine CLEAR3.
2) SETMAT uses variables in common /MATCOM/ (see Appendix).
3) Dimensional considerations of the array MAL in /MATCOM/ restrict the number of acceptable triples to 100.

Method:

Estimators have already been determined in subroutine MATCH for all possible triples of tracks from the 2 or 3 measured views. (If only two views are measured, the track number in view 3 is always 1.) These estimators are stored in the array FUNC(I, J, K) (see common /MATCOM/). It is also assumed that the last three bits of each FUNC value have been set to zero before the first call to SETMAT. The input variables I and IND fix a particular track in a particular view. SETMAT then searches through all the remaining combinations of tracks and views and finds the minimum FUNC value (FMINN).

<u>Example:</u> I=3, IND=2

SETMAT searches through all FUNC(J, 3, K) values where J and K take on all possible track number values.

The only triples excluded in this search are those whose value has been set to be 'bad' by subroutine MATCH (i. e. FUNC value equals COCON (see Appendix for /MATCOM/)). Once FMINN has been determined, an upper limit for acceptance is determined based on the IMF input value:

IF(IMF. LE. 2) EFMAX=min(CONS*FMINN, FMAX4)

IF(IMF. GT. 2) EFMAX=max(CONS*FMINN, FMAX4)

CONS is in /MATCOM/ and set by subroutine MACON.

FMAX4 is in /MATCOM/ and set by subroutine CLEAR3.

All possible triples having track I in view IND are now filtered and only those triples whose estimator (FUNC) value is less than EFMAX are accepted as possible match candidates. These triples are then stored in the array MAL(ICNT, I), ICNT being the counter for the accepted triple and I being the view. Since SETMAT is called many times by subroutine CLEAR3, the last three bits of the accepted triples (i. e. FUNC values) are flagged so that on subsequent calls to SETMAT, these triples will not be counted more than once. If more than 100 acceptable triples have already been found (i. e. ICNT. GE. 100), on any call to SETMAT, no more triples are accepted and SETMAT exits.

<u>CALLED BY</u>: CLEAR3

SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED:

PERTER

OR(X, Y) - performs a logical inclusive OR of X and Y. This is an intrinsic function for the IBM-FORTRANH compiler only.

AND(X, Y) - performs a logical AND of X and Y. This is an intrinsic function for the IBM-FORTRANH compiler only.

COMMON BLOCKS USED: /MATCOM/

TRKORD

For each match solution of each vertex of an event, TRKORD is entered via a call from DOMACH. It finds the beam track if there is one for the primary vertex, then orders all remaining tracks by charge, those with positive sign first followed by all tracks with ambiguous charge.

Usage:

CALL TRKORD (NVTX, ICHRG, NVWS)

Description of parameters:

NVTX - The vertex number.
(It is negative if there is no beam track for the event.)

ICHRG - Total charge at vertex NVTX.

NVWS - Number of measured views.

Remarks:

1) Beam constants must be known from a previous call to subroutine MACON.

2) Track characteristics must be known from a previous call to subroutine ALFAR. Such a call exists in MATCH.

3) TRKORD is called by subroutine DOMACH for each solution of each vertex of the current event.

Method:

If NVTX is negative, we do not search for a beam track and go directly to the charge ordering section of TRKORD. If we need to find a beam track at the primary vertex, we first ask if the user already knows that the first measured track or the last measured track in each view is the beam track (i.e. see KBFORC in common /MATCOM/). If so, we search the match solution triples for this track and reorder the tracks so that the beam track occurs first in the solution. If we have no prior knowledge of the beam track, we cycle over all tracks in all views to determine which track is the beam track based on charge, azimuth and film plane curvature considerations. If the triple representing any track has the correct charge, and its average azimuth and curvature fall within the tolerances set by subroutine MACON, this triple is then flagged as a good beam track candidate. If there is more than one beam track candidate or if no track is a good beam track, the triple whose azimuth is the closest to the beam azimuth is chosen as the beam track.

The match solutions are then reordered so that the beam track triple appears first. If a definite beam track has been found, its sign is set to be minus the sign of the beam. A test on total charge balance is next performed and if we find only one track of ambiguous charge, we set it to have the correct sign. Now we perform the charge ordering portion of TRKORD. Disregarding the beam track, we first order all tracks of positive charge to follow the beam track in the match solution. Then we order all tracks of ambiguous charge next. Those triples with negative charge will then automatically follow in the match solution. After charge ordering is done, we exit TRKORD.

<u>Tests for good beam track candidate:</u>

For each triple of tracks in the match solution:

<u>TEST 1</u>

The total sign of the triple must be minus the sign of the beam track, unless the beam is neutral. It must be minus the sign of the beam because all tracks are measured outward from the vertex.

<u>TEST 2</u>

The absolute error of beam azimuth and the average triple azimuth must be less than the error in the beam azimuth.

<u>TEST 3</u>

Let SAG be the minimum sagitta of the tracks (i. e. if the track sagitta is less than SAG, the track has ambiguous charge).

Let ANKLE = angle of tangent to a track at its mid-point.

Let CURV = curvature of a track.

Let EPBM = error in projected curvature as found in subroutine MACON.

For those tracks of the triple for which

$$CURV > SAG*|ANKLE|,$$

form the beam length on film as:

$$L = |ANKLE|/CURV \quad .$$

Define the error in the projected curvature of the beam as:

$$ERCBM = EPBM \qquad (L_{av} \geq 2.0)$$

$$ERCBM = EPBM/L_{av}^{5/2} \qquad (L_{av} < 2.0)$$

The absolute error of the projected curvature of the beam on the TVGP film plane and the average curvature must be less than ERCBM. Only those triples which successfully pass all three tests can be considered as good beam track candidates.

CALLED BY: DOMACH
SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED: None
COMMON BLOCKS USED: /MATCOM/

YTH

This subroutine is for the FNAL 15-foot BC optics. Depending upon an input variable (I), it relates the field angle (T) to the image height (Y) on the film plane or vice-versa. This transformation is approximate and only for the lenses (i. e. ignores the windows). Y is in centimeters, T is in radians.

The polynomial expression for T into Y and vice-versa were obtained from the following data for the FNAL bubble chamber lens as supplied by Optical Research Associates, 550 North Rosemead Blvd., Pasadena, CA 91107 (3/10/72).

Field Angle (degrees)	Image Height (inches)
0.0	0.0
4.5	.112335
9.0	.224888
13.5	.337894
18.0	.451625
22.5	.566408
27.0	.682661
31.5	.800940
36.0	.922021
40.5	1.047054
45.0	1.177907
49.5	1.318076
54.0	1.476000

Note: This data implies $Y_{max} = 3.74904$ cm.

$T_{max} = 54.0$ deg. $= .94248$ rad.

The polynomial expansions are as follows:

$$T = c_1Y + c_2Y^3 + c_3Y^5 + c_4Y^7 + c_5Y^9$$

$$Y = a_1T + a_2T^3 + a_3T^5 + a_4T^7 + a_5T^9 + a_6T^{11}$$

c_1 =	.2753366	a_1 =	3.631244
c_2 =	-.001061617	a_2 =	.2047306
c_3 =	-.4309289E-04	a_3 =	-.04030262
c_4 =	.8238782E-06	a_4 =	.5980015
c_5 =	-.7169469E-07	a_5 =	-.8435869
		a_6 =	.5472297

When converting from field angle to image height, it is assumed that on input Y = cos(T). On output T is the field angle and Y the corresponding image height.

CALLED BY: MATCH, various routines in 15-foot TVGP
SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED: None
COMMON BLOCKS USED: None

APPENDIX A

LABELED COMMON BLOCKS AND THEIR CONTENTS

Common Block /ANLIN/

COMMON/ANLIN/ IN(2000), PTSV(400, 7), VPTSV(400, 7)

IN - Input record information for the event.

PTSV - Track coordinate information in the various TVGP film planes, and pupil shift coordinate information.

VPTSV - Contains information similar to the array PTSV but only for the various vertices of an event.

The contents of the arrays IN, PTSV, and VPTSV are as follows:

The array IN

WORD	CONTENTS
1	(No. of words in record)-1 or -1 for EOF
2	No. of fiducials in View 1.
3	No. of fiducials in View 2.
4	No. of fiducials in View 3.
5	No. of fiducials in View 4.
6	No. of vertices in View 1.
7	No. of vertices in View 2.
8	No. of vertices in View 3.
9	No. of vertices in View 4.
10	No. of tracks in View 1.
11	No. of tracks in View 2.
12	No. of tracks in View 3.
13	No. of tracks in View 4.
14	Pointer to ID block (block of event information).
15	Pointer to fiducial labels.
16	Pointer to x-coordinates of fiducials.
17	Pointer to y-coordinates of fiducials.
18	Pointer to vertex labels (currently set to 0).
19	Pointer to vertex x-coordinates.
20	Pointer to vertex y-coordinates.
21	Pointer to track labels including stopping tracks.
22	Pointer to No. of hits (currently set to 0).
23	Pointer to No. of misses (currently set to 0).
24	Pointer to widths (currently set to 0).
25	Pointer to No. of points/track/view.
26	Pointer to location of points/track/view.
27	Pointer to track x-coordinates

28	Pointer to track y-coordinates.
29	No. of words in ID block.
30	Roll - (4 digits)
31	Frame - (4 digits)
32	Event No. - (1 digit)
33	Measurement No. - (1 digit)
34	Type (currently set to 0)
35	Zone (currently set to 0)
36	Missing views (1 or 2 digit number)
37	Experiment No. - (3 digits)
38	Operator No. - (2 digits)
39	Machine No. - (1 digit)
40	Measurement date - YYMMDD
41	Measurement program version (currently set to 0)
42	Magnetic field - (4 digits)
43	10* scan No. + rules No.
44-48	Palmer Code (topology)
49-58	Zones
59-78	Comments
79-end of rec.	Information pointed to by pointer words.

N. B. A pointer word points to one location below the starting address of the desired information (i. e. if IN(16)=179, then the fiducial x-coordinates begin at IN(180)).

N. B. If the measurements were done on the ANL POLLY III, words 18, 22, 23, 24, 34, 35 and 41 may not be zero.

The array PTSV

(1, 1) - (400, 1)	X-coordinates ordered consecutively by track and view of all tracks in the TVGP 'ideal' film plane (1 cm from lens, all optical distortions removed).
(1, 2) - (400, 2)	Y-coordinates ordered consecutively of all tracks in the TVGP 'ideal' film plane.
(1, 3) - (400, 3)	X-coordinates ordered consecutively of all tracks in the TVGP 'tilted' film plane.
(1, 4) - (400, 4)	Y-coordinates ordered consecutively of all tracks in the TVGP 'tilted' film plane.
(1, 5) - (400, 5)	Spatial x-coordinates ordered consecutively of pupil shifts for all points.

(1, 6) - (400, 6) Spatial y-coordinates ordered consecutively of pupil shifts for all points.

(1, 7) - (400, 7) Spatial z-coordinates ordered consecutively of pupil shifts for all points.

The array VPTSV

This array is constructed similarly to the array PTSV but contains only the corresponding information for the vertices of the event.

The arrays PTSV and VPTSV are set up by the TVGP routine REDGEN.

Common Block /DOMACH/

COMMON/DOMACH/ NCTL, NTRKT, LOCS, LOCH, LOCM, LOCW, LOCN, LOCL, NTTSL(20, 3, 10), ISVH(20, 3), ISVH(20, 3), ISVL(20, 3), ISVM(20, 3), ISVN(20, 3), ISVN(20, 3), ISVS(20, 3), ISVW(20, 3), ISTOP(12, 3), JFAIL

NCTL - Total number of tracks for the event as determined from the input record.

NTRKT - Location counter pointing to track information in ISVL, ISVN, and ISVS arrays.

LOCS - Pointer to stopping information in input record.

LOCH - Pointer to hits information in input record.

LOCM - Pointer to misses information in input record.

LOCW - Pointer to widths information in input record.

LOCN - Pointer to number of points/track information in input record.

LOCL - Pointer to label information in input record.

NTTSL - Full event solution array
NTTSL(I, J, K) = measured track number for event track I in view J of solution K.

ISVH - Array of hit information.

ISVL - Array of label information.

ISVM - Array of misses information.

ISVN - Array of number of points/track/view information.

ISVS - Array of stopping information.

ISVW - Array of widths information.

ISTOP - Array of stopping information/vertex.
ISTOP(I, J) = 0 implies track I in view J is not a stopper.
= 256 implies track I in view J is a stopper.

JFAIL - Match fail code for current vertex.

/DOMACH/ is necessary for overlay purposes only and must be inserted into the main root of an overlay structure.

Common Block /MATCHL/

COMMON/MATCHL/ TOMIN, TOMAX, THRMIN, THRMAX, ICHMBR

TOMIN, TOMAX	- Minimum and maximum range values for the triple estimators formed when matching using the END-POINT match facility. (If end-point matching is not desirable, set TOMIN=TOMAX=0.0.)
THRMIN, THRMAX	- Minimum and maximum range values for the triple estimators formed when matching using the CURVATURE match facility. (If curvature matching is not desirable, set THRMIN=THRMAX=0.0.)
ICHMBR	- Parameter defining bubble chamber 12 - ANL 12-foot bubble chamber 15 - FNAL 15-foot bubble chamber

Common Block /MATCOM/

```
COMMON/MATCOM/  AZBM, COCON, ISPEC, CONS, EAZBM,
                EPBM, FLIM, FMAX, FMAX4, ICNT,
                IPRNTF, IPRNTU, ISINBM, ITRY, NSL,
                NTR, NTOPOL, NTSL, NTTSIN, PBM, SAG,
                CRVRAT, SINFLD, ALFA(12, 3), ANKLE(12, 3),
                PCAM(2, 3), CURV(12, 3), FUNC(12, 12, 12),
                IADD(12, 3), MAL(100, 3), NRT(12, 3),
                NSIN(12, 3), NTOT(12, 3), NTRK(3), SINE(12, 3),
                TANG(12, 3), KBFORC
DIMENSION NSOL(12, 3, 10)
EQUIVALENCE (NSOL(1, 1, 1), FUNC(1, 1, 1))
```

AZBM	Beam azimuth in radians.
COCON	Flag variable set up by MATCH and used by subroutine SETMAT. It equals 10^5 * maximum triple estimator with the last 3 bits set to 0.
IPSEC	Debug parameter useful for checking already 'prematched' solutions. 0 - Has no effect on match solutions. 1 - If the match solutions do not contain the 'prematched' solution, this solution is added to the match solution set before exiting from MATCH. The 'prematched' solution is assumed to be the order in which the tracks appear in the track bank for each view.) 2 - Same as ISPEC=1 but only for 2-view events. 3 - No match solution → same as ISPEC=1 Match solution found → same as ISPEC=2
CONS	See FLIM, FMAX.
EAZBM	Error in beam azimuth (radians).
EPBM	Error in beam momentum (MeV/c).
FLIM, FMAX	For three-view triads, all triples with an estimator .LE. CONS*FMIN are accepted as possible solutions. However, two limits are imposed. All triple estimators greater than FMAX are rejected. (If curvature match is not desired, set FLIM=FMAX=0.0.)
FMAX4	Fraction of FMAX used in subroutine CLEAR3 and SETMAT to filter out acceptable triads.

ICNT	Counter used in subroutine CLEAR3 to see how many tracks are acceptable.
IPRNTF	TVGP debug print flag.
IPRNTU	Debug logical print unit set by subroutine MACON.
ISINBM	Charge of the beam track.
ITRY	Counter used by subroutine CLEAR3 to determine how many times subroutine SETMAT has been entered with a new value of FMAX4.
NSL	Variable used by subroutine TRKORD to designate the current match solution to be processed by TRKORD.
NTR	Total number of tracks at the current vertex.
NTOPOL	Total number of tracks at the current vertex as determined by topology.
NTSL	Total number of match solutions found.
NTTSIN	Total charge at the current vertex.
PBM	Beam momentum (MeV/c).
SAG	Minimum sagitta of tracks. If any track has a sagitta .LT. SAG, its charge is assumed to be ambiguous.
CRVRAT	Variable used by subroutine CLEAR3 to filter the final solution set. Let CURFUN(IS) be the average triple estimator for solution IS and CURMIN be the minimum value of the array CURFUN. Let RATIO=CURFUN(IS)/CURMIN if the maximum triple estimator is greater than 1.0. If the maximum triple estimator is less than 1.0, let RATIO=LOG(CURMIN)/LOG(CURFUN(IS)). Solution 'IS' is rejected if RATIO is .LT.0 or .GT. CRVRAT.
SINFLD	Sign of the magnetic field (magnitude = 1.0) (see subroutine MACON).
ALFA(12, 3)	ALFA(I, J) is the tangent to track I in view J at its mid-point.
ANKLE(12, 3)	ANKLE(I, J) is the cosine of the angle of turn of track I in view J.
PCAM(2, 3)	PCAM(1, J) is minus the x-coordinate (in space) of the camera in view J. PCAM(2, J) is minus the y-coordinate (in space) of the camera in view J.
CURV(12, 3)	CURV(I, J) is the curvature of track I in view J.
FUNC(12, 12, 12)	FUNC(I, J, K) is the quality estimator assigned by subroutine MATCH to the triple (or triad) of track I in view 1, track J in view 2, and track K in view 3. N.B. This array is also equivalenced to the array NSOL (12, 3, 10) which on output from subroutine MATCH contains the match solution. NSOL(I, J, K) contains for the K-th solution, the number of the track in view J which is associated with the match solution track I.

IADD(12, 3)	IADD(I, J) is used by subroutine CLEAR3 and SETMAT and is equal to the total number of acceptable triads which contain track I in view J.
MAL(100, 3)	MAL(I, J) is used by subroutine CLEAR3 and SETMAT and is equal to the track number in view J for the acceptable triad I.
NRT(12, 3)	Location pointer used by subroutine MATCH to get the (x, y) coordinates of the tracks from the track bank.
NSIN(12, 3)	NSIN(I, J) is the sign of track I in view J.
NTOT(12, 3)	NTOT(I, J) is the total number of points measured for track I in view J.
NTRK(3)	NTRK(I) is the number of tracks in view I for the current vertex.
SINE(12, 3)	SINE(I, J) is the sign of track I in view J.
TANG(12, 3)	TANG(I, J) is the tangent to track I in view J at its mid-point.
KBFORC	Beam track flag used by subroutine MATCH and TRKORD. 0 - Do not force any track to be the beam track. -1 - Force the first track of the first vertex in each view to be the beam track. -2 - Force the last track of the first vertex in each view to be the beam track.

Common Block /MATHST/

COMMON/MATHST/ VAL, JFLAG

VAL - Value of triple estimator.
JFLAG - Histogram indicator

1 - VAL is the triple estimator for the END-POINT match.
2 - VAL is the triple estimator for the CURVATURE match.
3 - VAL is the triple estimator for the two-view triples comprising the match solution set only.
4 - VAL is the triple estimator for the 3-view triples comprising the match solution set only.

N.B. For JFLAG=1, 2, the values of VAL do not include triples which are forced to be good or forced to be bad by MATCH.

The common blocks, /OPTC12/ and blank common which are intrinsic to the ANL 12-foot, 15-foot TVGP program are used by DOMACH and MATCH. The parameters used by these subroutines are listed below:

<u>blank common</u>

DOMACH: BCPAR, OSPAR, IFAIL, IDBLK
MATCH: BCPAR, OSPAR

<u>/OPTC12/</u>

MATCH: EMAG, II, TRANS

APPENDIX B

SAMPLE DEBUG PRINTOUT FROM THE MATCH PACKAGE

****

15-FT. BUBBLE CHAMBER EVENTS
MATCH CONSTANTS

DESCRIPTION	VALUE	PARAMETER NAME	
BEAM ID.	ANTINEUTRINO	IHULL	
CHARGE OF THE BEAM TRACK	0.	ISINBM	
BEAM MOMENTUM (MEV/C)	0.2000E 06	PBM	} DUMMY VARIABLES SINCE BEAM IS KNOWN TO BE THE FIRST MEASURED TRACK IN EACH VIEW ✓
ERROR IN BEAM MOMENTUM (MEV/C)	0.5000E 06	EPBM	
BEAM AZIMUTH (RADIANS)	6.2500	AZBM	
ERROR IN BEAM AZIMUTH (RADIANS)	7.2400	EAZBM	
NOMINAL FIELD,(KILOGAUSS),NEGATIVE IF POINTING INTO CAMERAS	25.3000	BFIELD	
NOMINAL DEMAGNIFICATION	150.0000	DEMAG	
RANGE OF TRIPLE ESTIMATOR FOR GOOD CURVATURE MATCH	(0.100E-13, 0.100E-05)	(FLIM,FMAX)	
RANGE OF TRIPLE ESTIMATOR FOR GOOD ENDPOINT MATCH	(0.200E 02, 0.170E 03)	(TCMIN,TCMAX)	
FLOATING MULTIPLIER FOR ACCEPTABLE TRIPLES	2.0000	CONS	
FLOATING MULTIPLIER FOR NUMBER OF ACCEPTABLE AMBIGUOUS SOLUTIONS	1.1000	CRVRAT	
PREMATCHED SOLUTION INDICATOR	3	ISPEC	
FORCED BEAM TRACK INDICATOR	-1	KBFORC	← FORCE FIRST TRACK IN EACH VIEW TO MATCH.

****

CALCULATED PROJECTED CURVATURE OF BEAM AND ERROR= 0.5692493E-02 0.1423123E-01

EXAMPLE 1

```
*******************************************************************************************************
      MATCH DEBUG PRINTOUT FOR:
 RCLL=  43  FRAME= 780  EVT.#=1  MISSING VIEW=24  TOPOLCGY =N1-T
   NTOPCL=    2              NTTSIN=    1      SAG= 0.994475E-03  VERTEX 1
```

TWO VIEW EVENT (2 VERTICES)

FIRST TRACK IN EACH VIEW MATCHED.

```
 ISTCP( 1, 1)=  0 |
 ISTCP( 2, 1)=  0 |  NO STOPPERS
 ISTCP( 1, 2)=  0 |
 ISTCP( 2, 2)=  0 |
THERE ARE   2  POINTS FOR TRACK1  IN VIEW1
THERE ARE   2  POINTS FOR TRACK1  IN VIEW2
THERE ARE  11  POINTS FOR TRACK2  IN VIEW1
THERE ARE  11  POINTS FOR TRACK2  IN VIEW2
```

TRACK	VIEW	SINE	ALFA	CURV	TAN	ANGLE
1	1	0.0	1.69525 0C	0.0	-7.4939E 00	0.0
1	2	0.0	1.2013E 0C	0.C	2.5817E 0C	C.C
2	1	8.0155E-03	1.6870E 00	1.6161E 00	-8.566CE CC	5.4E47E-C1
2	2	6.5523E-03	1.4591E CC	4.8864E-01	8.9120E 00	5.6721F-01

```
TRACK SIGNS FOLLOW
 0 1******************** 0 1*******************************************
   NLSTRK=  0     EST.          X-SPACE        Y-SPACE        Z-SPACE      VIEW PAIR
 ( 2, 2, 1)      0.173E 04      -86.373       -55.504        143.523        1 + 2
               **** TRACK  2  2  1      RAT= 0.172811E 04 ****
                                                  <- BAD ENDPOINT MATCH
     FUNC( 1, 1, 1)= 0.100000E-39 ]
     FUNC( 2, 1, 1)= 0.169999E 08 ]
     FUNC( 1, 2, 1)= C.169999E C8 ]  1st CALL TO CLEAR3
     FUNC( 2, 2, 1)= 0.172811E 04 ]
     FUNC( 1, 1, 2)= 0.0
     FUNC( 2, 1, 2)= 0.0
     FUNC( 1, 2, 2)= 0.0
     FUNC( 2, 2, 2)= 0.0
     FUNC( 1, 1, 1)= 0.100000E-39 ]
     FUNC( 2, 1, 1)= 0.169999E 08 ]
     FUNC( 1, 2, 1)= C.169999E C8 ]  2nd. CALL TO CLEAR3
     FUNC( 2, 2, 1)= 0.172811E 04 ]
     FUNC( 1, 1, 2)= 0.0
     FUNC( 2, 1, 2)= 0.0
     FUNC( 1, 2, 2)= 0.0
     FUNC( 2, 2, 2)= 0.0
     FUNC( 1, 1, 1)= 0.100000E-39 ]
     FUNC( 2, 1, 1)= 0.169999E 08 ]
     FUNC( 1, 2, 1)= 0.169999E C8 ]  3rd. CALL TO CLEAR3
     FUNC( 2, 2, 1)= 0.172811E 04 ]
     FUNC( 1, 1, 2)= 0.0
     FUNC( 2, 1, 2)= 0.0
     FUNC( 1, 2, 2)= 0.0
     FUNC( 2, 2, 2)= 0.0
          RETURN FROM MATCH WITH  1  SOLUTIONS
*******************************************************************************************************

 IFAIL=  0  MATCH SCLN. 1  - 1 1- 2 2-
```

```
*************************************************************************************************************
        MATCH DEBUG PRINTOUT FOR:
  ROLL=  43  FRAME= 780  EVT.#=1  MISSING VIEW=24  TOPOLOGY =N1-T
    NTOPOL=     2              NTTSIN=     0        SAG= 0.994475E-03  VERTEX 2

   ISTCP( 1, 1)=  0 )
   ISTCP( 2, 1)=  0 }  NO STOPPERS
   ISTOP( 1, 2)=  0 }
   ISTCP( 2, 2)=  0 )
  THERE ARE    6  POINTS FOR TRACK1  IN VIEW1
  THERE ARE    6  POINTS FOR TRACK1  IN VIEW2
  THERE ARE    5  POINTS FOR TRACK2  IN VIEW1
  THERE ARE    7  POINTS FOR TRACK2  IN VIEW2

     TRACK       VIEW          SINE           ALFA          CURV           TAN         ANGLE

        1          1   -6.1118E-04    1.3258E 00    5.0585E 01    3.9996E 00    8.6729E-01
        1          2   -1.3206E-03    1.3294E 00    6.4411E 01    4.0616E 00    6.6553E-01
        2          1   -2.6206E-04    4.3160E 00    1.2628E 02    2.3895E 00    8.6152E-01
        2          2   -7.7833E-04    3.8410E 00    2.3890E 01    3.4121E-01    9.2564E-01

TRACK SIGNS FOLLOW
 0 0********************-1 0****************************************
     NLSTRK=  0
 ( 1, 1, 1)        0.511E 02      -132.625          -51.605        255.944           1 + 2
                       **** TRACK   1  1  1       RAT= 0.511466E 02 **** GOOD ENDPOINT MATCH
 ( 1, 2, 1)        0.221E 03      -126.766          -50.392        246.337           1 + 2
                       **** TRACK   1  2  1       RAT= 0.220808E 03 **** BAD ENDPOINT MATCH
 ( 2, 1, 1)        0.286E 03      -136.368          -55.243        259.632           1 + 2
                       **** TRACK   2  1  1       RAT= 0.285711E 03 **** BAD ENDPOINT MATCH
 ( 2, 2, 1)        0.128E 02      -130.230          -53.853        249.345           1 + 2
                       **** TRACK   2  2  1       RAT= 0.127538E 02 **** GOOD ENDPOINT MATCH
     FUNC( 1, 1, 1)= 0.511459E 02 ]
     FUNC( 2, 1, 1)= 0.285711E 03 ]
     FUNC( 1, 2, 1)= 0.220793E 03 ]  1ST. CALL TO CLEAR1
     FUNC( 2, 2, 1)= 0.127530E 02 ]
     FUNC( 1, 1, 2)= 0.0
     FUNC( 2, 1, 2)= 0.0
     FUNC( 1, 2, 2)= 0.0
     FUNC( 2, 2, 2)= 0.0

            RETURN FROM MATCH WITH  1  SOLUTIONS
*************************************************************************************************************

IFAIL=  0  MATCH SOLN. 1  - 2 2- 1 1-
```

EXAMPLE 2

THREE VIEW EVENT (3 VERTICES)

COMBINED END-POINT AND CURVATURE MATCH USED.

FIRST TRACK OF EACH VIEW MATCHED.

```
************************************************************************************************
     MATCH DEBUG PRINTOUT FOR:
 ROLL=  43  FRAME=1343  EVT.#=1  MISSING VIEW= 4  TOPOLOGY =N1-T-T
   NTOPOL=     2             NTTSIN=    1      SAG= C.994475E-03   VERTEX 1

  ISTOP( 1, 1)=  C
  ISTOP( 2, 1)=  C
  ISTOP( 1, 2)=  C      NO STOPPERS
  ISTOP( 2, 2)=  C
  ISTOP( 1, 3)=  0
  ISTOP( 2, 3)=  0
 THERE ARE   2  POINTS FOR TRACK1  IN VIEW1
 THERE ARE   2  POINTS FOR TRACK1  IN VIEW2
 THERE ARE   2  POINTS FOR TRACK1  IN VIEW3
 THERE ARE   5  POINTS FOR TRACK2  IN VIEW1
 THERE ARE   8  POINTS FOR TRACK2  IN VIEW2
 THERE ARE   7  POINTS FOR TRACK2  IN VIEW3

    TRACK       VIEW          SINE         ALEA        CURV          TAB          ANGLE

       1          1   0.0            3.5207E CC   0.0          3.9840E-01    0.0
       1          2   0.0            3.9842E 0C   0.C          1.1216E 0C    0.C
       1          3   0.0            3.3712E 00   0.C          2.3371E-01    0.0
       2          1   1.7593E-04     6.0327E CC   2.1128E C1  -2.5593E-01    9.6514E-01
       2          2   6.1423E-05     5.7299F 0C   2.1414E CC  -3.6874E-C1    9.5927E-C1
       2          3   1.2297E-04     1.3723E-02   3.2009E 00   1.3724E-02    9.7837E-C1

TRACK SIGNS FOLLOW
 0 0********************* 0 0********************* 0 0*********************
    NLSTRK=  0      EST.            X-SPACE     Y-SPACE     Z-SPACE     VIEW PAIR
 ( 2, 2, 2)       0.8655 02         29.526      74.528      200.157      1 + 2
                  GOOD              29.755      73.956      199.736      2 + 3
                                    29.675      74.112      199.764      3 + 1
                **** TRACK  2  2  2        RAT= 0.35C63E-10 ****
                                                  ↑
                                 END-POINT ESTIMATOR TRANSFORMED TO CURVATURE ESTIMATOR RANGE
    FUNC( 1, 1, 1)= C.1C0000E-39
    FUNC( 2, 1, 1)= 0.999999F-01
    FUNC( 1, 2, 1)= 0.999999E-01
    FUNC( 2, 2, 1)= C.999999E-C1
    FUNC( 1, 1, 2)= 0.999999E-01    1ST. CALL TO CLEAR3
    FUNC( 2, 1, 2)= C.999999E-01
    FUNC( 1, 2, 2)= C.999999E-01
    FUNC( 2, 2, 2)= 0.353626E-10

           RETURN FROM MATCH WITH  1  SOLUTIONS
************************************************************************************************

IFAIL=  C  MATCH SCLN. 1  - 1 1 1- 2 2 2-
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MATCH DEBUG PRINTOUT FOR:
ROLL=  43   FRAME=1343   EVT.#=1   MISSING VIEW= 4   TOPOLOGY =N1-T-T
  NTOPCL=    2            NTTSIN=     0      SAC= 0.554475E-03   VERTEX 2

ISTOP( 1, 1)=  0
ISTOP( 2, 1)=  0
ISTOP( 1, 2)=  0
ISTOP( 2, 2)=  0     NO STOPPERS
ISTOP( 1, 3)=  0
ISTOP( 2, 3)=  0
THERE ARE    5   POINTS FOR TRACK1   IN VIEW1
THERE ARE    5   POINTS FOR TRACK1   IN VIEW2
THERE ARE    7   POINTS FOR TRACK1   IN VIEW3
THERE ARE    7   POINTS FOR TRACK2   IN VIEW1
THERE ARE    9   POINTS FOR TRACK2   IN VIEW2
THERE ARE    9   POINTS FOR TRACK2   IN VIEW3

    TRACK      VIEW          SINE          ALFA          CURV           TAN          ANGLE

      1          1   -3.8963E-06   2.9379E 00   3.7234E-01   -2.0660E-01   9.9999E-01
      1          2   -1.2014E-05   2.7981E 00   4.8671E-01   -3.5771E-01   9.9999E-01
      1          3    6.8052E-05   3.1834E 00   2.1653E 00    4.1864E-02   9.9941E-01
      2          1    3.0454E-03   3.7161E-01   1.1066E 01    3.9771E-01   6.6701E-01
      2          2    3.3774E-03   2.7620E-01   7.5123E 00    2.8345E-01   8.9791E-01
      2          3    2.6019E-03   3.8849E-01   7.3692E 00    4.0929E-01   9.2067E-01

TRACK SIGNS FOLLOW
0 1******************** 0 1******************** 0 1********************
   NLSTRK=  0
( 1, 1, 1)     0.752E 02        28.917       73.937       198.706        1 + 2  )  Good end-point match
                                28.460       73.890       196.722        2 + 3  )
               GOOD             28.754       73.803       197.628        3 + 1  )
                    **** TRACK  1  1  1      RAT= 0.87979E-11 ****
( 1, 1, 2)     0.141E 04        28.917       73.937       198.706        1 + 2  )  Bad end-point match, try curvature match
                                33.435       76.845       203.434        2 + 3  )
               BAD              32.840       78.114       212.073        3 + 1  )
     FILM COORDINATES OF TRACK TRIPLE( 1, 1, 2)
             VIEW 1                           VIEW 2                           VIEW 3
     (       0.6859,       0.4897)  (      -0.0697,        0.9607)  (      -0.0662,        0.0146)
     (       0.6840,       0.4899)  (      -0.0728,        0.9619)  (      -0.0616,        0.0157)
     (       0.6815,       0.4906)  (      -0.0756,        0.9628)  (      -0.0573,        0.0167)
     (       0.6794,       0.4911)  (      -0.0793,        0.9643)  (      -0.0504,        0.0185)
     (       0.6770,       0.4915)  (      -0.0830,        0.9655)  (      -0.0454,        0.0203)
     (       0.0   ,       0.0   )  (       0.0   ,        0.0   )  (      -0.0363,        0.0239)
     (       0.0   ,       0.0   )  (       0.0   ,        0.0   )  (      -0.0294,        0.0272)
     (       0.0   ,       0.0   )  (       0.0   ,        0.0   )  (      -0.0236,        0.0305)
     (       0.0   ,       0.0   )  (       0.0   ,        0.0   )  (      -0.0162,        0.0351)
PT. NO.   BEST VIEW       RT           PCHI        WGT               (X,Y) IN SLAVE VIEWS
   2          1                                                     NO CORRESPONDING POINT
   3          1                                                     NO CORRESPONDING POINT
   4          1                                                     NO CORRESPONDING POINT
PT. NO.   BEST VIEW       RT           PCHI        WGT               (X,Y) IN SLAVE VIEWS
   2          2                                                     NO CORRESPONDING POINT
   3          2                                                     NO CORRESPONDING POINT
   4          2                                                     NO CORRESPONDING POINT
PT. NO.   BEST VIEW       RT           PCHI        WGT               (X,Y) IN SLAVE VIEWS
   2          3                                                     NO CORRESPONDING POINT
   3          3                                                     NO CORRESPONDING POINT
   4          3                                                     NO CORRESPONDING POINT
   5          3                                                     NO CORRESPONDING POINT
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   6        3                                                     NO CORRESPONDING POINT
   7        3                                                     NO CORRESPONDING POINT
   8        3                                                     NO CORRESPONDING POINT
                  **** TRACK  1  1  2    RAT= 0.10000E 00 ****   → BAD
 ( 1, 2, 1)     0.168E 04       33.608       81.100       210.977       1 + 2
                  BAD           22.268       74.150       199.183       2 + 3
                                28.754       73.803       197.828       3 + 1
      FILM COORDINATES OF TRACK TRIPLE( 1, 2, 1)
              VIEW 1                          VIEW 2                          VIEW 3
        (      0.6859,      0.4897)  (      -0.0697,      0.9607)  (     -0.0662,      0.0146)
        (      0.6840,      0.4899)  (      -0.0642,      0.9613)  (     -0.0691,      0.0145)
        (      0.6815,      0.4906)  (      -0.0574,      0.9618)  (     -0.0717,      0.0145)
        (      0.6794,      0.4911)  (      -0.0523,      0.9629)  (     -0.0738,      0.0144)
        (      0.6770,      0.4915)  (      -0.0439,      0.9645)  (     -0.0767,      0.0141)
        (      0.0   ,      0.0   )  (      -0.0344,      0.9673)  (     -0.0792,      0.0140)
        (      0.0   ,      0.0   )  (      -0.0281,      0.9696)  (     -0.0821,      0.0140)
        (      0.0   ,      0.0   )  (      -0.0190,      0.9732)  (      0.0   ,      0.0   )
        (      0.0   ,      0.0   )  (      -0.0119,      0.9771)  (      0.0   ,      0.0   )
 PT. NO.  BEST VIEW      RT              PCHI          WGT               (X,Y) IN SLAVE VIEWS
   2          1       0.28828E-06    0.57121E-0?        1.     (  -0.0667,    0.9611)  (  -0.0686,    0.0146)
   3          1       0.10806E-05    0.54860E-09        2.     (  -0.0679,    0.9609)  (  -0.0723,    0.0144)
   4          1       0.24432E-05    0.21892E-?7        3.     (  -0.0650,    0.9608)  (  -0.0755,    0.0142)
 PT. NO.  BEST VIEW      RT              PCHI          WGT               (X,Y) IN SLAVE VIEWS
   2          2                                                   NO CORRESPONDING POINT  }
   3          2                                                   NO CORRESPONDING POINT  }
   4          2                                                   NO CORRESPONDING POINT  }
   5          2                                                   NO CORRESPONDING POINT  } FAIL
   6          2                                                   NO CORRESPONDING POINT  }
   7          2                                                   NO CORRESPONDING POINT  }
   8          2                                                   NO CORRESPONDING POINT
 PT. NO.  BEST VIEW      RT              PCHI          WGT               (X,Y) IN SLAVE VIEWS
   2          3                                                   NO CORRESPONDING POINT
   3          3                                                   NO CORRESPONDING POINT
   4          3                                                   NO CORRESPONDING POINT
   5          3                                                   NO CORRESPONDING POINT
   6          3                                                   NO CORRESPONDING POINT
                  **** TRACK  1  2  1    RAT= 0.10000E 00 ****  → BAD
 ( 1, 2, 2)     0.753E 03       33.608       81.190       210.977       1 + 2
                  BAD           37.236       77.107       203.946       2 + 3
                                32.340       78.114       212.073       3 + 1
      FILM COORDINATES OF TRACK TRIPLE( 1, 2, 2)
              VIEW 1                          VIEW 2                          VIEW 3
        (      0.6859,      0.4897)  (      -0.0697,      0.9607)  (     -0.0662,      0.0146)
        (      0.6840,      0.4899)  (      -0.0642,      0.9613)  (     -0.0616,      0.0157)
        (      0.6815,      0.4906)  (      -0.0574,      0.9618)  (     -0.0573,      0.0167)
        (      0.6794,      0.4911)  (      -0.0523,      0.9629)  (     -0.0504,      0.0185)
        (      0.6770,      0.4915)  (      -0.0439,      0.9645)  (     -0.0454,      0.0203)
        (      0.0   ,      0.0   )  (      -0.0344,      0.9673)  (     -0.0363,      0.0239)
        (      0.0   ,      0.0   )  (      -0.0281,      0.9696)  (     -0.0294,      0.0272)
        (      0.0   ,      0.0   )  (      -0.0190,      0.9732)  (     -0.0235,      0.0305)
        (      0.0   ,      0.0   )  (      -0.0119,      0.9771)  (     -0.0162,      0.0351)
 PT. NO.  BEST VIEW      RT              PCHI          WGT               (X,Y) IN SLAVE VIEWS
   2          1                                                   NO CORRESPONDING POINT  ]
   3          1                                                   NO CORRESPONDING POINT  ] FAIL
   4          1                                                   NO CORRESPONDING POINT
 PT. NO.  BEST VIEW      RT              PCHI          WGT               (X,Y) IN SLAVE VIEWS
   2          2                                                   NO CORRESPONDING POINT
   3          2                                                   NO CORRESPONDING POINT
   4          2                                                   NO CORRESPONDING POINT
   5          2                                                   NO CORRESPONDING POINT
   6          2                                                   NO CORRESPONDING POINT
   7          2                                                   NO CORRESPONDING POINT
   8          2                                                   NO CORRESPONDING POINT
 PT. NO.  BEST VIEW      RT              PCHI          WGT               (X,Y) IN SLAVE VIEWS
   2          3                                                   NO CORRESPONDING POINT
   3          3                                                   NO CORRESPONDING POINT
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      4          3                                                    NO CORRESPONDING POINT
      5          3                                                    NO CORRESPONDING POINT
      6          3                                                    NO CORRESPONDING POINT
      7          3                                                    NO CORRESPONDING POINT
      8          3                                                    NO CORRESPONDING POINT
                    **** TRACK  1  2  2     RAT= 0.10000E 00 **** BAD
  ( 2, 1, 1)     0.717E 03       32.648        71.255       193.827        1 + 2
                    BAD          28.460        73.890       198.722        2 + 3
                                 32.678        73.097       190.712        3 + 1
        FILM COORDINATES OF TRACK TRIPLE( 2, 1, 1)
                VIEW 1                           VIEW 2                          VIEW 3
        (     0.6859,      0.4897)  (     -0.0697,      0.9607)  (     -0.0662,      0.0146)
        (     0.6923,      0.4904)  (     -0.0728,      0.9619)  (     -0.0691,      0.0143)
        (     0.7003,      0.4927)  (     -0.0756,      0.9628)  (     -0.0717,      0.0145)
        (     0.7075,      0.4948)  (     -0.0793,      0.9643)  (     -0.0738,      0.0144)
        (     0.7141,      0.4977)  (     -0.0830,      0.9655)  (     -0.0767,      0.0141)
        (     0.7241,      0.5029)  (      0.0   ,      0.0   )  (     -0.0792,      0.0142)
        (     0.7294,      0.5066)  (      0.0   ,      0.0   )  (     -0.0821,      0.0140)
   PT. NO.  BEST VIEW       RT            PCHI          WGT            (X,Y) IN SLAVE VIEWS
      2          1                                                    NO CORRESPONDING POINT  ]
      3          1                                                    NO CORRESPONDING POINT  ]
      4          1                                                    NO CORRESPONDING POINT  ]  FAIL
      5          1                                                    NO CORRESPONDING POINT  ]
      6          1                                                    NO CORRESPONDING POINT
   PT. NO.  BEST VIEW       RT            PCHI          WGT            (X,Y) IN SLAVE VIEWS
      2          2                                                    NO CORRESPONDING POINT
      3          2                                                    NO CORRESPONDING POINT
      4          2                                                    NO CORRESPONDING POINT
   PT. NO.  BEST VIEW       RT            PCHI          WGT            (X,Y) IN SLAVE VIEWS
      2          3                                                    NO CORRESPONDING POINT
      3          3                                                    NO CORRESPONDING POINT
      4          3                                                    NO CORRESPONDING POINT
      5          3                                                    NO CORRESPONDING POINT
      6          3                                                    NO CORRESPONDING POINT
                    **** TRACK  2  1  1     RAT= 0.10000E 00 **** BAD
  ( 2, 1, 2)     0.141E 04       32.648        71.255       193.827        1 + 2
                                 33.435        76.645       203.434        2 + 3
                    BAD          36.843        77.047       205.609        3 + 1
        FILM COORDINATES OF TRACK TRIPLE( 2, 1, 2)
                VIEW 1                           VIEW 2                          VIEW 3
        (     0.6859,      0.4897)  (     -0.0697,      0.9607)  (     -0.0662,      0.0146)
        (     0.6923,      0.4904)  (     -0.0728,      0.9619)  (     -0.0616,      0.0157)
        (     0.7003,      0.4927)  (     -0.0756,      0.9628)  (     -0.0573,      0.0167)
        (     0.7075,      0.4948)  (     -0.0793,      0.9643)  (     -0.0504,      0.0185)
        (     0.7141,      0.4977)  (     -0.0830,      0.9655)  (     -0.0454,      0.0203)
        (     0.7241,      0.5029)  (      0.0   ,      0.0   )  (     -0.0363,      0.0239)
        (     0.7294,      0.5066)  (      0.0   ,      0.0   )  (     -0.0294,      0.0272)
        (     0.0   ,      0.0   )  (      0.0   ,      0.0   )  (     -0.0236,      0.0305)
        (     0.0   ,      0.0   )  (      0.0   ,      0.0   )  (     -0.0162,      0.0351)
   PT. NO.  BEST VIEW       RT            PCHI          WGT            (X,Y) IN SLAVE VIEWS
      2          1                                                    NO CORRESPONDING POINT  ]
      3          1                                                    NO CORRESPONDING POINT  ]  FAIL
      4          1                                                    NO CORRESPONDING POINT  ]
      5          1                                                    NO CORRESPONDING POINT  ]
      6          1                                                    NO CORRESPONDING POINT
   PT. NO.  BEST VIEW       RT            PCHI          WGT            (X,Y) IN SLAVE VIEWS
      2          2                                                    NO CORRESPONDING POINT
      3          2                                                    NO CORRESPONDING POINT
      4          2                                                    NO CORRESPONDING POINT
   PT. NO.  BEST VIEW       RT            PCHI          WGT            (X,Y) IN SLAVE VIEWS
      2          3                                                    NO CORRESPONDING POINT
      3          3                                                    NO CORRESPONDING POINT
      4          3                                                    NO CORRESPONDING POINT
      5          3                                                    NO CORRESPONDING POINT
      6          3                                                    NO CORRESPONDING POINT
      7          3                                                    NO CORRESPONDING POINT
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   8          3                                                         NO CORRESPONDING POINT
                     **** TRACK  2  1  2      RAT= 0.10000E 00 **** BAD
   ( 2, 2, 1)      0.168E 04         37.439         78.076       205.333        1 + 2
                     BAD             32.268         74.150       199.183        2 + 3
                                     32.678         73.097       190.712        3 + 1
        FILM COORDINATES OF TRACK TRIPLE( 2, 2, 1)
                 VIEW 1                               VIEW 2                           VIEW 3
           (      0.6859,       0.4897)  (     -0.0697,       0.9607)  (     -0.0662,        0.0146)
           (      0.6923,       0.4904)  (     -0.0642,       0.9613)  (     -0.0691,        0.0145)
           (      0.7003,       0.4927)  (     -0.0574,       0.9618)  (     -0.0717,        0.0145)
           (      0.7075,       0.4948)  (     -0.0523,       0.9629)  (     -0.0738,        0.0144)
           (      0.7141,       0.4977)  (     -0.0439,       0.9645)  (     -0.0767,        0.0141)
           (      0.7241,       0.5029)  (     -0.0344,       0.9673)  (     -0.0792,        0.0140)
           (      0.7294,       0.5066)  (     -0.0281,       0.9696)  (     -0.0821,        0.0140)
           (      0.0    ,      0.0    ) (     -0.0190,       0.9732)  (      0.0   ,         0.0   )
           (      0.0    ,      0.0    ) (     -0.0119,       0.9771)  (      0.0   ,         0.0   )
   PT. NO.  BEST VIEW       RT                PCHI        WGT                (X,Y) IN SLAVE VIEWS
     2          1                                                        NO CORRESPONDING POINT
     3          1                                                        NO CORRESPONDING POINT
     4          1                                                        NO CORRESPONDING POINT    FAIL
     5          1                                                        NO CORRESPONDING POINT
     6          1                                                        NO CORRESPONDING POINT
   PT. NO.  BEST VIEW       RT                PCHI        WGT                (X,Y) IN SLAVE VIEWS
     2          2                                                        NO CORRESPONDING POINT
     3          2                                                        NO CORRESPONDING POINT
     4          2                                                        NO CORRESPONDING POINT
     5          2                                                        NO CORRESPONDING POINT
     6          2                                                        NO CORRESPONDING POINT
     7          2                                                        NO CORRESPONDING POINT
     8          2                                                        NO CORRESPONDING POINT
   PT. NO.  BEST VIEW       RT                PCHI        WGT                (X,Y) IN SLAVE VIEWS
     2          3                                                        NO CORRESPONDING POINT
     3          3                                                        NO CORRESPONDING POINT
     4          3                                                        NO CORRESPONDING POINT
     5          3                                                        NO CORRESPONDING POINT
     6          3                                                        NO CORRESPONDING POINT
                     **** TRACK  2  2  1      RAT= 0.10000E 00 **** BAD
   ( 2, 2, 2)      0.195E 03         37.439         78.076       205.333        1 + 2
                                     37.238         77.107       203.886        2 + 3
                     BAD             36.843         77.097       203.605        3 + 1
        FILM COORDINATES OF TRACK TRIPLE( 2, 2, 2)
                 VIEW 1                               VIEW 2                           VIEW 3
           (      0.6859,       0.4897)  (     -0.0697,       0.9607)  (     -0.0662,        0.0146)
           (      0.6923,       0.4904)  (     -0.0642,       0.9613)  (     -0.0616,        0.0157)
           (      0.7003,       0.4927)  (     -0.0574,       0.9618)  (     -0.0573,        0.0167)
           (      0.7075,       0.4948)  (     -0.0523,       0.9629)  (     -0.0504,        0.0185)
           (      0.7141,       0.4977)  (     -0.0439,       0.9645)  (     -0.0454,        0.0203)
           (      0.7241,       0.5029)  (     -0.0344,       0.9673)  (     -0.0363,        0.0239)
           (      0.7294,       0.5066)  (     -0.0281,       0.9696)  (     -0.0294,        0.0272)
           (      0.0    ,      0.0    ) (     -0.0190,       0.9732)  (     -0.0236,        0.0305)
           (      0.0    ,      0.0    ) (     -0.0119,       0.9771)  (     -0.0162,        0.0351)
   PT. NO.  BEST VIEW       RT                PCHI        WGT                (X,Y) IN SLAVE VIEWS
     2          1       0.36744E-07     0.23537E-09     1.    (  -0.0586,    0.9618)   (  -0.0580,    0.0165)
     3          1       0.12790E-06     0.21133E-08     2.    (  -0.0457,    0.9634)   (  -0.0504,    0.0185)
     4          1       0.40876E-07     0.30208E-08     3.    (  -0.0419,    0.9651)   (  -0.0413,    0.0218)
     5          1       0.13133E-06     0.68849E-08     4.    (  -0.0342,    0.9674)   (  -0.0350,    0.0245)
     6          1       0.90949E-06     0.43909E-07     5.    (  -0.0228,    0.9717)   (  -0.0268,    0.0286)
   PT. NO.  BEST VIEW       RT                PCHI        WGT                (X,Y) IN SLAVE VIEWS
     2          2       0.87402E-09     0.48503E-11     1.    (  -0.0596,    0.0161)   (   0.6870,    0.4898)
     3          2       0.26284E-09     0.80979E-11     2.    (  -0.0529,    0.0178)   (   0.6932,    0.4907)
     4          2       0.23283E-09     0.12201E-10     3.    (  -0.0477,    0.0195)   (   0.6979,    0.4920)
     5          2       0.32742E-10     0.13058E-10     4.    (  -0.0393,    0.0226)   (   0.7055,    0.4942)
     6          2       0.36380E-11     0.13189E-10     5.    (  -0.0299,    0.0269)   (   0.7139,    0.4976)
     7          2       0.36380E-11     0.13345E-10     6.    (  -0.0235,    0.0305)   (   0.7194,    0.5004)
     8          2                                                        NO CORRESPONDING POINT
   PT. NO.  BEST VIEW       RT                PCHI        WGT                (X,Y) IN SLAVE VIEWS
```

```
2   3   0.73669E-08   0.34986E-10   1.  (  0.6895,   0.4901)  (  -0.0662,   0.9611)
3   3   0.45848E-08   0.76803E-10   2.  (  0.6930,   0.4906)  (  -0.0619,   0.9615)
4   3   0.24761E-07   0.47944E-09   3.  (  0.7003,   0.4927)  (  -0.0550,   0.9623)
5   3   0.98371E-08   0.69174E-09   4.  (  0.7039,   0.4938)  (  -0.0500,   0.9633)
6   3   0.47279E-07   0.21750E-08   5.  (  0.7131,   0.4972)  (  -0.0409,   0.9654)
7   3   0.16197E-06   0.85078E-08   6.  (  0.7206,   0.5009)  (  -0.0339,   0.9675)
8   3                                      NO CORRESPONDING POINT
               **** TRACK  2  2  2     RAT= 0.94971E-10 ****  GOOD
  FUNC( 1, 1, 1)= 0.879786E-11
  FUNC( 2, 1, 1)= 0.999999E-01
  FUNC( 1, 2, 1)= 0.999999E-01
  FUNC( 2, 2, 1)= 0.999999E-01     1st CALL TO CLEAR3
  FUNC( 1, 1, 2)= 0.999999E-01
  FUNC( 2, 1, 2)= 0.999999E-01
  FUNC( 1, 2, 2)= 0.999999E-01
  FUNC( 2, 2, 2)= 0.949711E-10

          RETURN FROM MATCH WITH  1  SOLUTIONS
*****************************************************************************************************

IFAIL=  0  MATCH SOLN. 1  - 1 1 1- 2 2 2-
```

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*****************************************************************************************************************
        MATCH DEBUG PRINTOUT FOR:
  ROLL=  43  FRAME=1343  EVT.#=1  MISSING VIEW= 4  TOPOLOGY =N1-T-T
   NTOPOL=    2           NTTSIN=     0       SAG= 0.994475E-03  VERTEX 3

    ISTOP( 1, 1)=  0
    ISTOP( 2, 1)=  0
    ISTOP( 1, 2)=  0     No STOPPERS
    ISTOP( 2, 2)=  0
    ISTOP( 1, 3)=  0
    ISTOP( 2, 3)=  0
  THERE ARE    9  POINTS FOR TRACK1  IN VIEW1
  THERE ARE    7  POINTS FOR TRACK1  IN VIEW2
  THERE ARE   10  POINTS FOR TRACK1  IN VIEW3
  THERE ARE    9  POINTS FOR TRACK2  IN VIEW1
  THERE ARE    9  POINTS FOR TRACK2  IN VIEW2
  THERE ARE    9  POINTS FOR TRACK2  IN VIEW3

       TRACK        VIEW         SINE          ALFA          CURV          TAN          ANGLE

         1            1  -6.7431E-03   2.1955E 00   2.9324E 01  -1.3969E 00   2.6530E-01
         1            2  -7.0754E-03   2.2157E 00   2.6221E 01  -1.3275E 00   3.1280E-01
         1            3  -6.7394E-03   2.2202E 00   2.3849E 01  -1.3171E 00   3.9302E-01
         2            1   8.0149E-03   9.5029E-01   1.2315E 01   1.4915E 00   5.6518E-01
         2            2   6.2765E-03   1.4942E 00   7.6763E 00   1.3029E 01   3.0752E-01
         2            3   1.0690E-02   1.6317E 00   2.6056E 01  -1.6395E 01  -1.0841E-01

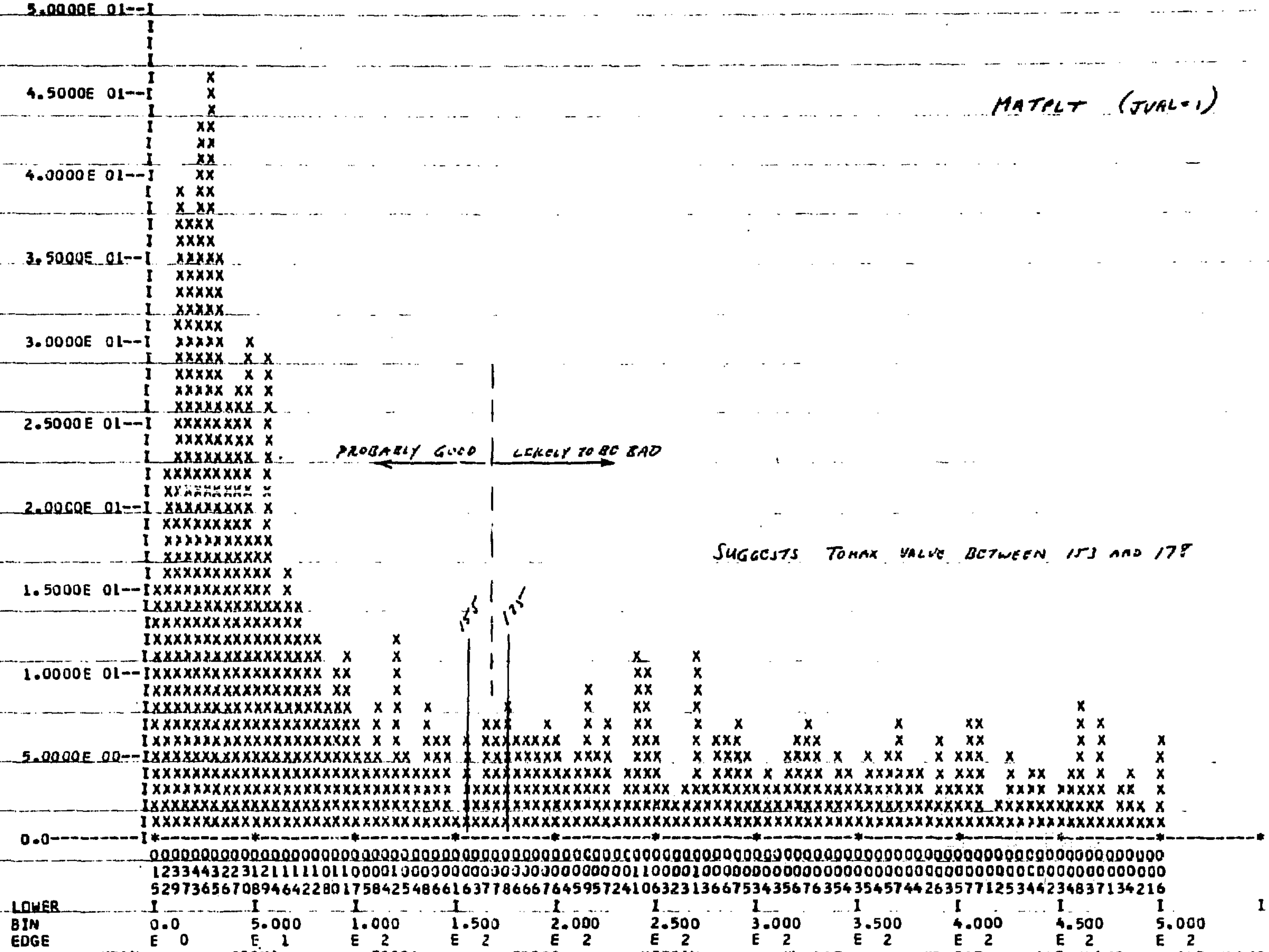
 TRACK SIGNS FOLLOW
 -1 1*********************-1 1*********************-1 1*********************
      NLSTRK=  0
 ( 1, 1, 1)       0.131E 03        20.372       38.597       226.203       1 + 2
                                   19.721       89.734       229.396       2 + 3
                    GOOD           20.169       89.392       229.736       3 + 1
                  **** TRACK  1  1  1      RAT= 0.79248E-03 ****  <-- TRANSFORMED TO CURVATURE MATCH RANGE
 ( 2, 2, 2)       0.408E 03        29.174       69.234       222.816       1 + 2
                                   26.787       91.980       225.473       2 + 3
                    BAD            23.232       90.731       222.005       3 + 1
      FILM COORDINATES OF TRACK TRIPLE( 2, 2, 2)
               VIEW 1                         VIEW 2                        VIEW 3
      (      0.6012,       0.4559)  (     -0.0256,      0.8450)  (     -0.0216,      0.0626)
      (      0.6075,       0.4598)  (     -0.0223,      0.8555)  (     -0.0160,      0.0652)
      (      0.6141,       0.4648)  (     -0.0198,      0.8635)  (     -0.0151,      0.0695)
      (      0.6203,       0.4708)  (     -0.0182,      0.8720)  (     -0.0124,      0.0750)
      (      0.6257,       0.4769)  (     -0.0167,      0.8818)  (     -0.0120,      0.0807)
      (      0.6322,       0.4864)  (     -0.0159,      0.8926)  (     -0.0123,      0.0894)
      (      0.6375,       0.4969)  (     -0.0160,      0.9042)  (     -0.0142,      0.0975)
      (      0.6416,       0.5113)  (     -0.0167,      0.9152)  (     -0.0181,      0.1059)
      (      0.6422,       0.5170)  (     -0.0194,      0.9286)  (     -0.0248,      0.1155)
 PT. NO.  BEST VIEW       RT           PCHI        WGT              (X,Y) IN SLAVE VIEWS
   2          1                                                  NO CORRESPONDING POINT
   3          1      0.71304E-09   0.11171E-10    1.    (  -0.0201,    0.8628)   (  -0.0175,    0.0658)
   4          1      0.22737E-10   0.11725E-10    2.    (  -0.0183,    0.8717)   (  -0.0150,    0.0695)
   5          1      0.81855E-11   0.11991E-10    3.    (  -0.0169,    0.8802)   (  -0.0134,    0.0732)
   6          1      0.32742E-10   0.13431E-10    4.    (  -0.0159,    0.8932)   (  -0.0121,    0.0795)
   7          1      0.22737E-10   0.14698E-10    5.    (  -0.0162,    0.9072)   (  -0.0119,    0.0867)
   8          1      0.73669E-10   0.19911E-10    6.    (  -0.0189,    0.9259)   (  -0.0140,    0.0972)
 PT. NO.  BEST VIEW       RT           PCHI        WGT              (X,Y) IN SLAVE VIEWS
   2          2      0.36380E-11   0.29674E-13    1.    (  -0.0185,    0.0649)   (   0.6077,    0.4600)
   3          2      0.58208E-10   0.99137E-12    2.    (  -0.0160,    0.0680)   (   0.6146,    0.4653)
   4          2      0.22737E-10   0.15635E-11    3.    (  -0.0144,    0.0710)   (   0.6205,    0.4711)
   5          2      0.58208E-10   0.35961E-11    4.    (  -0.0128,    0.0752)   (   0.6264,    0.4779)
```

```
   6           2                                                        NO CORRESPONDING POINT
   7           2                                                        NO CORRESPONDING POINT
   8           2        0.63725E-05    0.43663E-06      5.    (  -0.0127,    0.2769)    (    0.6395,    0.5933)
PT. NO.   BEST VIEW         RT            PLFI          WGT                (X,Y) IN SLAVE VIEWS
   2           3        0.89102E-07    0.39660E-09      1.    (   0.6126,    0.4636)    (  -0.0219,    0.8567)
   3           3        0.25670E-07    0.64314E-09      2.    (   0.6201,    0.4707)    (  -0.0189,    0.8680)
   4           3        0.89140E-08    0.79183E-09      3.    (   0.6277,    0.4796)    (  -0.0168,    0.8812)
   5           3        0.16088E-07    0.11253E-08      4.    (   0.6333,    0.4933)    (  -0.0159,    0.8923)
   6           3        0.45076E-04    0.13561E-05      5.    (   0.6392,    0.5005)    (  -0.0161,    0.8679)
   7           3        0.32742E-09    0.13561E-05      6.    (   0.6417,    0.5118)    (  -0.0192,    0.9235)
   8           3                                                        NO CORRESPONDING POINT
                       **** TRACK  2  2  2       RAT= 0.81956E-10 ****  GOOD
    FUNC( 1, 1, 1)= 0.792474E-03
    FUNC( 2, 1, 1)= 0.999999E-01
    FUNC( 1, 2, 1)= 0.999999E-01
    FUNC( 2, 2, 1)= 0.999999E-01      1st. CALL TO CLEAR3
    FUNC( 1, 1, 2)= 0.999999E-01
    FUNC( 2, 1, 2)= 0.999999E-01
    FUNC( 1, 2, 2)= 0.999999E-01
    FUNC( 2, 2, 2)= 0.819578E-10

              RETURN FROM MATCH WITH   1  SOLUTIONS
****************************************************************************************************************

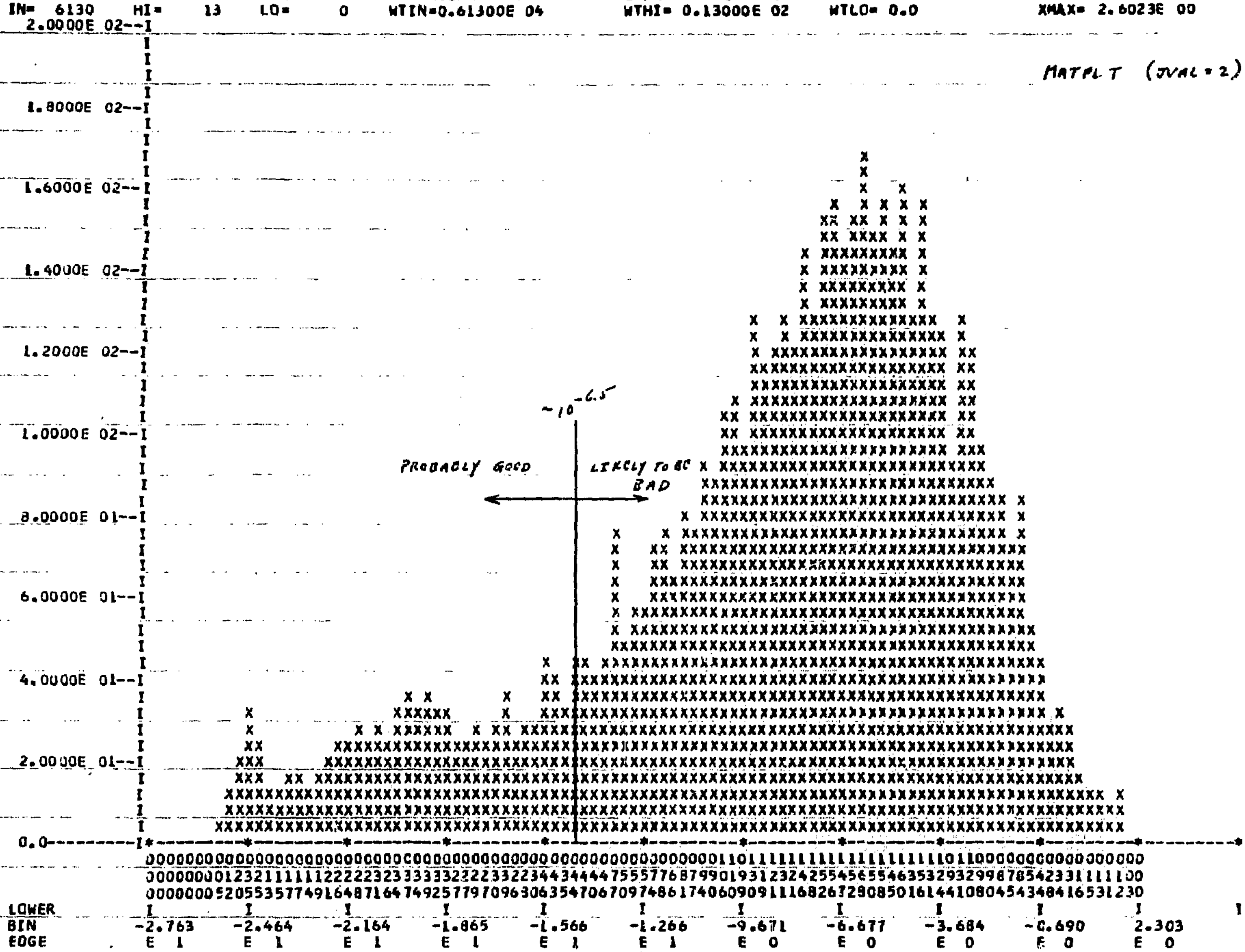
IFAIL=  0  MATCH SOLN. 1  - 1 1 1- 2 2 2-
```

HISTOGRAM #= 1: TRIPLE ESTIMATOR FOR END-POINT MATCH   EV/X= 1.0000E 00   BIN = 5.0000E 00   XMIN= 0.0
IN= 872   HI= 13673   LO= 0   WTIN=0.87200E 03   WTHI= 0.13673E 05   WTLO= 0.0   XMAX= 5.0500E 02



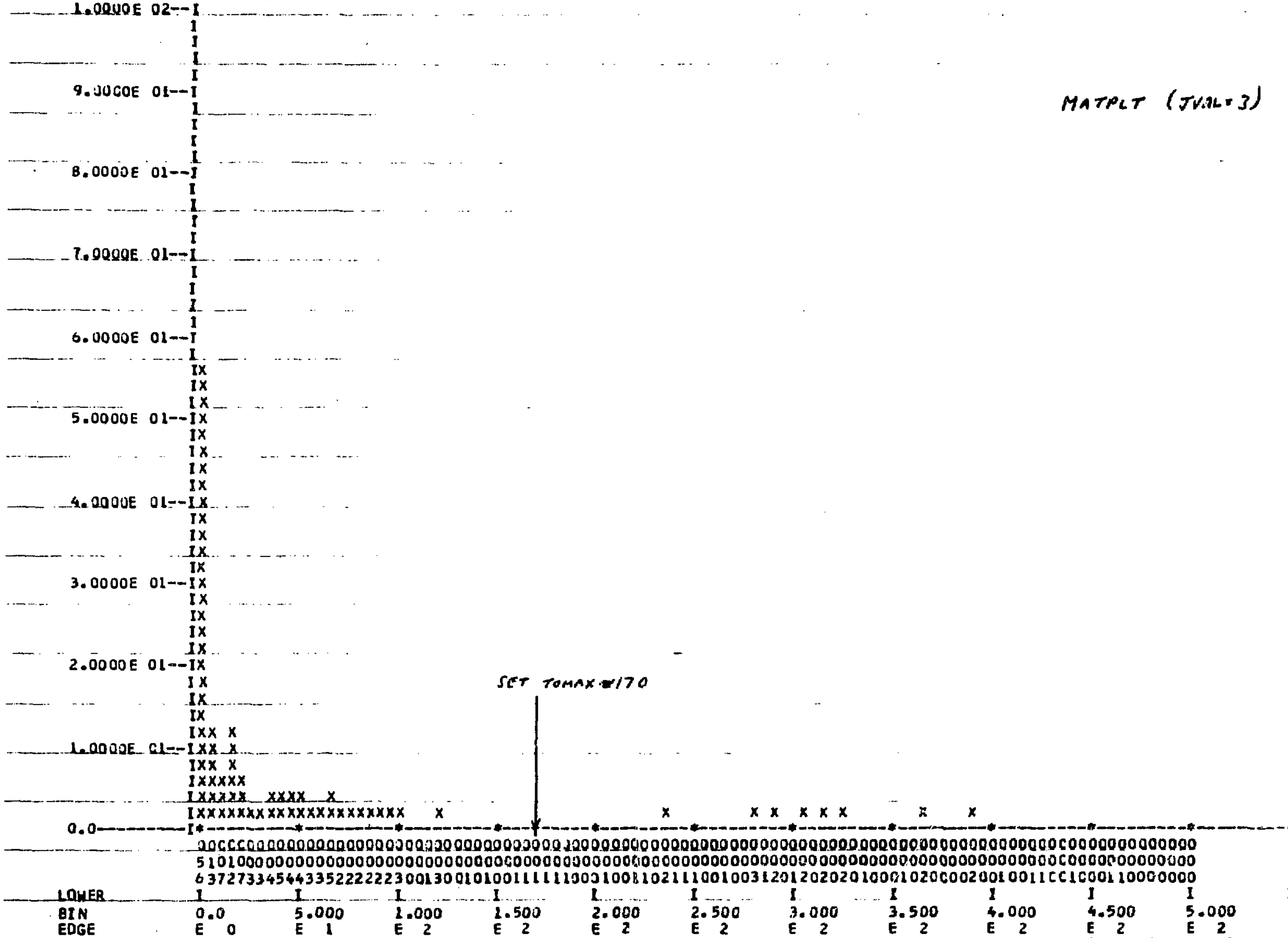
MEAN	SIGMA	ESIG1	ESIG2	MEDIAN	XL=16%	XR=84%	(XR+XL)/2	(XR-XL)/2
0.15294E 03	0.14483E 03	0.76842E 02	0.94734E 02	0.85625E 02	0.22962E 02	0.33377E 03	0.17837E 03	0.15540E 03

HISTOGRAM #= 2: LOG OF ESTIMATOR FOR CURVATURE MATCH EV/X= 4.0000E 00 BIN = 2.9934E-01 XMIN=-2.7631E 01
IN= 6130 HI= 13 LO= 0 WTIN=0.61300E 04 WTHI= 0.13000E 02 WTLO= 0.0 XMAX= 2.6023E 00



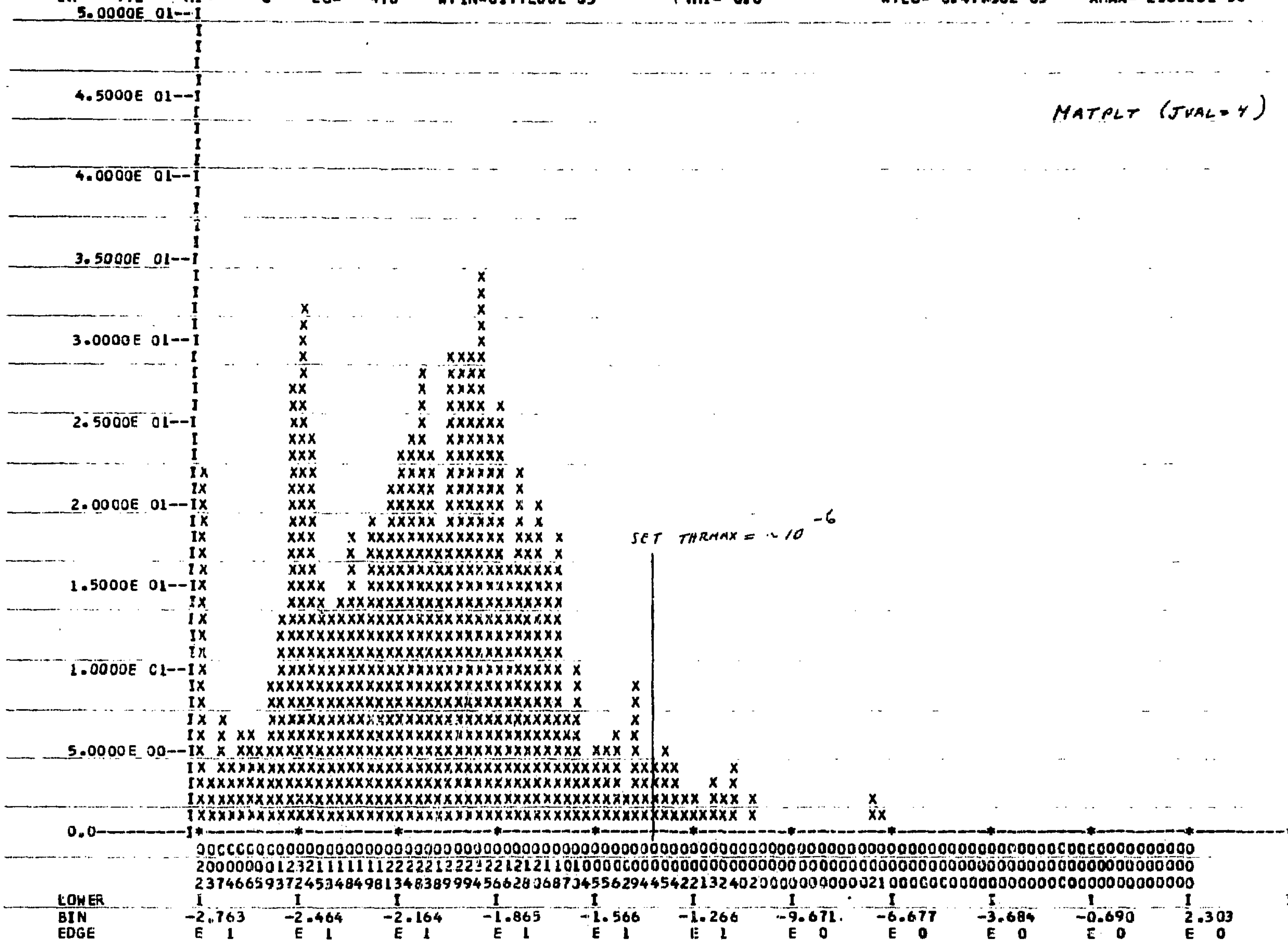
MEAN	SIGMA	FSIG1	FSIG2	MEDIAN	XL=16%	XR=84%	(XR+XL)/2	(XR-XL)/2
-0.87296E 01	0.58601E 01	0.69892E 02	0.94312E 02	-0.75074E 01	-0.14756E 02	-0.31853E 01	-0.89708E 01	0.57855E 01

HISTOGRAM #= 3: MATCH SOLUTION TRIPLE ESTIMATOR - 2 VIEW EV/X= 2.0000E 00 BIN = 5.0000E 00 XMIN= 0.0
IN= 190 HI= 42 LO= 0 WTIN=0.19000E 03 WTHI= 0.42000E 02 WTLO= 0.0 XMAX= 5.0500E 02



MEAN	SIGMA	FSIG1	FSIG2	MEDIAN	XL=16%	XR=84%	(XR+XL)/2	(XR-XL)/2
0.86289E 02	0.12052E 03	0.82296E 02	0.93124E 02	0.25000E 02	0.26939E 01	0.23707E 03	0.11988E 03	0.11719E 03

HISTOGRAM #= 4: MATCH SOLUTION TRIPLE ESTIMATOR - 3 VIEW   WY/X= 1.0000E 00   BIN = 2.9934E-01   XMIN=-2.7631E 01
IN= 772   HI= 0   LO= 478   WT IN=0.77200E 03   WTHI= 0.0   WTLO= 0.47800E 03   XMAX= 2.6023E 00



MEAN	SIGMA	FSIG1	FSIG2	MEDIAN	XL=16%	XR=84%	(XR+XL)/2	(XR-XL)/2
-0.20539E 02	0.35896E 01	0.66599E 02	0.96809E 02	-0.20473E 02	-0.24445E 02	-0.17223E 02	-0.20834E 02	0.36111E 01