THRESH - BASIC CERN GEOMETRY PROGRAMME

by

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General description of THRESH for heavy liquid chambers

THRESH was written for the geometrical reconstruction of events in hydrogen, so that we can assume that tracks are very close to helices.

However, before any helix-fitting is done, points are reconstructed in space, taking into account the refraction of the lightrays in the different media. These general principles can also be used for heavy liquid events.

We could consider THRESH as divided into two parts :

- the first one consisting in reconstructing points in space,
- the second one, consisting of the helix fit through these points.

I will describe THRESH as it is used up to now, thus with the helix fit, but for heavy liquid this helix fit could be replaced by a more adequate method, as the one proposed by M. Huybrechts.

The first part has also to be improved to give more accurate reconstructed points in space. This was not imperative for tracks in hydrogen, because these reconstructed points are only used to find a first approximation of the helix.

Improvements which are proposed, are

1) the choice of the 2 best views is made for each measurement in turn, as prescribed by H. Burmeister;

2) a secondary order interpolation to find corresponding points in space, as prescribed by W.G. Moorhead.

A very general flow of the THRESH for heavy liquid is shown on page 35, while a more detailed flow, with the characteristics of the different programmes now used, is given on page 37.

Introduction

The programme described here is the IBM 709 version of the Mercury programme, described by W.G. Moorhead in (ref. 6) to which I shall make frequent reference.

The original translation of the Mercury programme into Fortran was done at Sacley, as part of a collaboration. The Saclay progamme is called GAP 2 (ref 4), and has been considerably modified for CERN needs, to become THRESH.

For several months a new set of programmes (ref.1) has been used in the HEP group to analyse bubble chamber events. These programmes are REAP, THRESH, GRIND and COOK.

REAP is a Ferranti-Mercury programme which reads the paper tapes coming from the measuring machines, orders the data in reconstruction lists, and gives an output in BCD onto a magnetic tape. The reading and sorting part of this programme consists of the input programme of G.R. Macleod (ref.2.). The way in which the measurements have to be done and conventions for labelling points and tracks are given in the report (ref.2). The magnetic tape, being REAP output, contains for each event a set of BCD records.

THRESH reads this magnetic tape, one event at a time, and does the geometrical reconstruction in space of each event. THRESH is a programme written for IBM 709, the calculations being written in FORTRAN, and the routines dealing with output on tapes in FAP (ref.3). This report handles the way in which the event is reconstructed in space. More details about the programme will be found in the manual.

GRIND and COOK are finally the programmes which analyse physically the events (ref. 5).

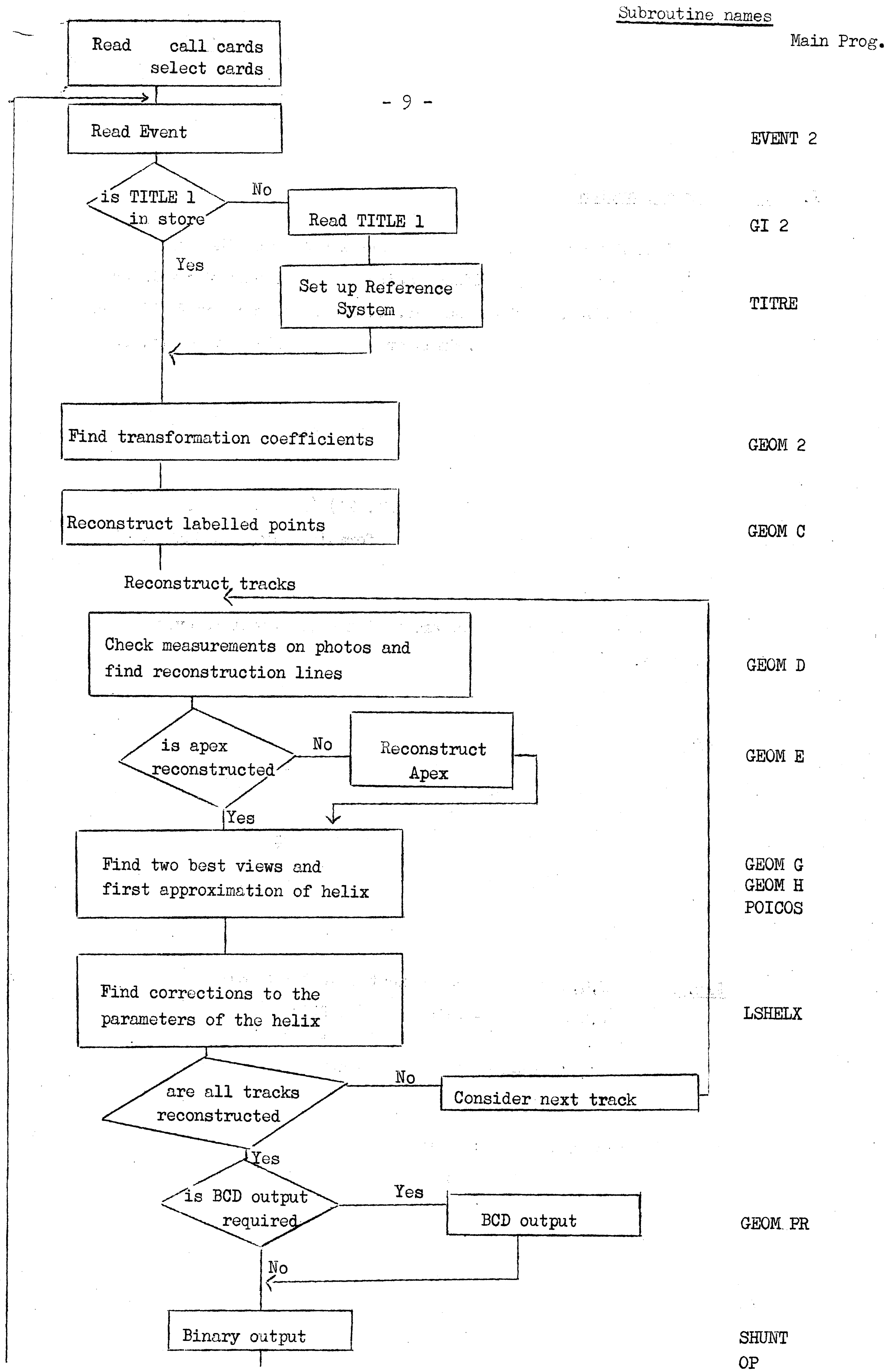
General description of THRESH

The geometrical reconstruction in space of an event is made, using measurements on a maximum of 4 stereoscopic views.

It is assumed that the bubble chamber is in a uniform magnetic field, perpendicular to the front glass, so that the changed particles can be considered to describe helices. For each track, THRESH finds the parameters of this helix, and its location in the bubble chamber with respect to an orthogonal axis system (see fig 1) of which the x - y plane is defined by the position of fiducial marks. The measurements on the different views are all transformed to a common reference system which is defined by the apparent positions of the fiducial marks on the back of the front glass. The data needed to make up this reference system e.g. camera co-ordinates, refractive indices and thicknesses of the different media, are kept in a "TITLE 1", and are relevant for a whole series of events, i.e. an experiment. "TITLE 1" for the different experiments are kept on a magnetic tape: the "General Data tape" from which THRESH selects the TITLE 1 appropriate for the events being reconstructed.

The measurements of a whole event are read from the output tape from REAP, or any other tape which gives this data in the same format, and the reconstruction is made. In general outline, the method is followed which was used in the previously used geometry programme (ref. 6). The least squares helix fitting procedure is still used, but elsewhere some modifications have been made, of which the most important is a different method of finding the first approximation of the helices.

A flow diagram gives the sequence in which the calculations are done in THRESH. More details about the programme itself can be found in the THRESH manual, in which future changes will be noted.


Subroutine names
Main Prog.
Read call cards
select cards
Read Event
EVENT 2
is TITLE 1 in store
No
Read TITLE 1
GI 2
Yes
Set up Reference System
TITRE
Find transformation coefficients
GEOM 2
Reconstruct labelled points
GEOM C
Reconstruct tracks
Check measurements on photos and find reconstruction lines
GEOM D
is apex reconstructed
No
Reconstruct Apex
GEOM E
Yes
Find two best views and first approximation of helix
GEOM G
GEOM H
POICOS
Find corrections to the parameters of the helix
LSHELX
are all tracks reconstructed
No
Consider next track
Yes
is BCD output required
Yes
BCD output
GEOM PR
No
Binary output
SHUNT
OP

I. The reference system

THRESH starts by reading the serial number of the event to be processed, and checks if the TITLE 1 which has to be used for this event is already into store. If it was not, it reads the correct TITLE 1 and does the following calculations, which are used for all the events, using this TITLE 1.

1) Sines and cosines of the angle between the x-axis and the line joining each pair of cameras.

2) The apparent positions (F', G') (see fig. 1) of the fiducial marks on the plane z = 0. The formulas given in CERN 60-33 (p.33) are used.

When these calculations are finished the complete event is read in and stored.

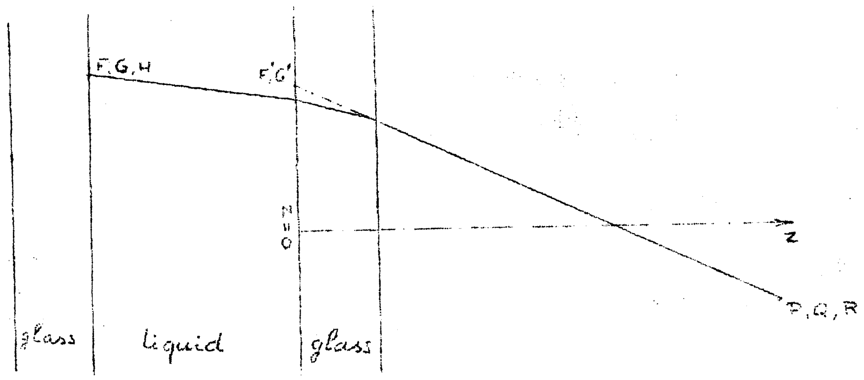


Fig. 1

P,Q,R	are the co-ordinates of the camera	) given in TITLE 1
F,G.H	the co-ordinates of a fiducial mark (here on the back glass)	)
F',G'	co-ordinates of the apparent position of that fiducial mark.	

The axis system is : z = 0 in the back of the frontglass
z is positive towards the cameras.

II. Coefficients of transformation to the reference plane z = 0

For each view in turn we find the coefficients, which describe the transformation of IEP measurements on a photograph, to the reference plane z = 0. We consider the most general transformation

$$\begin{aligned} F' &= \alpha_1 + \alpha_2 F + \alpha_3 G \\ G' &= \alpha_4 + \alpha_5 F + \alpha_6 G \end{aligned} \qquad \text{(II.1)}$$

where F,G are the IEP measurements, F',G' the apparent positions on z = 0 plane.

Equations (II.1) are solved for each view, by least squares to give α_i, using the (F,G) of all the measured fiducial marks in the view. We have already calculated independently (F',G') for these points, as described in the previous section.

The method of least squares is used to give an estimate of the quality of the measurements, because by back substitution (in II.1) we find again F',G', which are compared with the values found in the previous section (the tolerance is given in the TITLE 1). We obtain a test on the constancy of the film position when some fiducials are measured before and some after the rest of the view.

To find 6 independent α_i by least squares, we need at least 4 measured fiducial marks. However, when only 3 fiducials are measured, the programme will also find the transformation coefficients, but then we assume two more conditions

$$\begin{aligned} \alpha_2 &= \pm \alpha_6 \\ \alpha_3 &= \mp \alpha_5 \end{aligned} \qquad \text{(II.2)}$$

which mean that the co-ordinate system on the photograph and the system in the chamber defined by the TITLE 1 have to be orthogonal, and the magnification to go from one system to the other has to be the same in x and y direction. The upper signs are used when the systems are either both right-handed or both left-handed – the lower signs are used when one system is right-handed and the other left-handed.

Using conditions (II.2), we can again do the back-substitution and have an idea of the quality of the measurements.

When only two fiducials are measured in a view, it would still be possible to find the transformation coefficients with conditions (II.2), but in the TITLE should be mentioned which pair of signs is needed.

III. Reconstruction of labelled points

A light-ray between a point in space and its measurement on a photograph is described in the chamber by the equations

$$x = F_x z + G_x \qquad \text{(III.1)}$$

$$y = F_y z + G_y \qquad \text{(III.2)}$$

The formulas which give the coefficients F_x, G_x, F_y, G_y are given in CERN 60-33 (p.31 (I.3), (I.4)). We call the line, which is described by (III.1) and (III.2), a reconstruction line. For each measurement we can find such a "reconstruction line".

If a point is measured in at least two views, its co-ordinates in space (x, y, z) are found as the intersection of its reconstruction lines. Solving a system of equations (III.1), (III.2) by least squares, using all the measurements for this point, we find x, y, z with their standard errors Δx, Δy, Δz.

If $(\Delta x + \Delta y + \Delta z)$ is greater than a given value, given in the TITLE 1, the result is rejected and the reconstruction is tried again using one view less. If none of the possible combinations of two views give a good reconstruction (i.e. $\Sigma\Delta >$ tolerance), the point is only reconstructed if it is the beginning point of a track, since we need the co-ordinates of the beginning point to make a helix fit to the track. We proceed then in the following way :

We ignore the measurements given for this point, and instead we use the first measurement on the track in one view for which we find the co-ordinates in space (x, y, z), by the method of near correspondings points (see Appendix A) using the two first measurements on the track in another view. This method is also used when the beginning point of a track is not measured as a labelled point.

If a labelled point is measured only in one view, this point will again be reconstructed only if it is a beginning point of a track; the method of corresponding points is used again but using the given measurement.

IV. Reconstruction of tracks

For each track the following steps are followed :

1) Some checks are made on the measurements of the track on each photograph.

2) The coefficients F_x, G_x, F_y, G_y of the reconstruction lines are found for each measurement.

3) The points in space are found, corresponding with all the measurements of one view.

4) A helix is fitted through these points, and its parameters used as a first approximation.

5) Errors are calculated using the first approximation.

6) The best helix is found by least squares using the measurements on all views.

1. Checks made on the photographs

a) The measurements X_i, Y_i of the track are arranged by considering the distance of these measurements to the measurement of the apex, (or the first point on the track if the apex was not measured in that view.) The measurements are put in order of increasing distances from the beginning point. If two measurements at the same distance from the beginning point, only the first will be kept.

b) We define a new orthogonal axis system (X_T, Y_T) so that X_T passes through the first and last measurement on the track. Therefore we rotate the X axis through an angle

$$\arctan \frac{Y_N - Y_1}{X_N - X_1}$$

In the system (X_T, Y_T), a circle is fitted to the measurements by least squares.

$$a_o + a_1 X_T + a_2 (X_T^2 + Y_T^2) = Y_T \qquad \text{(IV. 1,1)}$$

If the measurement which is at the greatest orthogonal distance away from this circle, is further away than the tolerance in fringes (given in TITLE 1), this measurement is rejected and the circle refitted. If a second bad measurement is found, the view will not be used to reconstruct the track.

2. Reconstruction line for each measurement

For each measurement-pair on the track we then find the coefficients F_x, G_x, F_y, G_y which describe the light-ray

$$x = F_x z + G_x \tag{IV. 2,1}$$

$$y = F_y z + G_y \tag{IV. 2,2}$$

They are found as in CERN 60-33 (p.31 (I3), (I4)) as mentioned in Section III.

At this point we check if the beginning point of the track was reconstructed. If it was not found as a labelled point, we find it by the method of near corresponding points, as described in Section III.

3. Corresponding points on the helix

To find the first approximation of the track in space we use the method of near corresponding points, as described in Appendix A. We have first to choose the two best views, and we will find the points in space which correspond with the measurements in view α.

a) View α is chosen to be the one on which we see the track most nearly as an orthogonal projection, i.e. that in which the average value of $F_x^2 + F_y^2$ over all measurements is smallest.

b) For view β we choose the one, such that the line joining the two cameras α and β makes the greatest angle with the tangent to the track at the beginning point *

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* For a very curved track it is better to choose view β again for each measurement.

We write this condition as :

$$\sin (\phi - \vartheta_{\alpha,\beta}) \text{ is maximum.}$$

where ϕ is the angle between the x-axis and the tangent to the track at the considered point. We find an approximation to this angle ϕ by fitting a circle which passes through (A, B, C) (A, B, C being the co-ordinates of the beginning point), and the intersections (x_i, y_i) of all the light-rays describing the measurements in view α, with the plane z = C.

$$(x - A)^2 + (y - B)^2 + \lambda_1 (x - A) + \lambda_2 (y - B) = 0 \qquad \text{(IV. 3,1)}$$

The centre of this circle is $(A - \frac{\lambda_1}{2} , B - \frac{\lambda_2}{2})$

therefore

$$\tan \phi = - \frac{x - (A - \frac{\lambda_1}{2})}{y - (B - \frac{\lambda_2}{2})} \qquad \text{(IV. 3,2)}$$

For each measurement on view α, we must find the two nearest corresponding measurements on view β. Between these two we find by linear interpolation the reconstruction line in view β for the point whose measurement we consider in view α. In this way we find a set of points x_i, y_i, z_i with which we find a first approximation to the helix.

4. First approximation of the helix

The helix which is fitted is described by :

$$x' = \rho\ (\cos \vartheta - 1) \tag{IV. 4,1}$$

$$y' = \rho\ \sin \vartheta \tag{IV. 4,2}$$

$$z' = \rho\ \vartheta \tan \alpha \tag{IV. 4,3}$$

The axis system (x', y', z') is the original system (x, y, z) rotated through an angle β about the z-axis and translated to a new origin (A, B, C). (See fig. 2).

The parameters which we have to find are :

ρ = the radius of the helix

$\tan \alpha$ = tangent of the dip angle

β = the asimuthal angle of the beginning point, considering the x-axis as zero

A,B,C the co-ordinates of the beginning point of the track, and which are considered as known in first approximation, calculated in Section III.

- ρ and β are found by fitting a circle by least squares through the projections of the points $(x_i\ y_i\ z_i)$ on the plane $z = 0$.

$$(x_i - A)^2 + (y_i - B)^2 + \lambda_1\ (x_i - A) + \lambda_2 (y_i - B) = 0$$

thus

$$\rho = \tfrac{1}{2}\sqrt{\lambda_1^2 + \lambda_2^2} \qquad \text{(IV. 4,4)}$$

$$\beta = \arctan \frac{\lambda_2}{\lambda_1} \qquad \text{(IV. 4,5)}$$

To find an approximation for $\tan\alpha$, we have to assign an asimuthal angle ϑ_i to each reconstructed point in space

$$\vartheta_i = \arctan \frac{y_i - (B - \frac{\lambda_2}{2})}{x_i \quad (A - \frac{\lambda_1}{2})} - \beta \qquad \text{(IV. 4,6)}$$

For angle ϑ_i smaller than 0.02 we use instead

$$\vartheta_i = \frac{(y_i - B)\cos\beta - (x_i - A)\sin\beta}{\rho} \qquad \text{(IV. 4,7)}$$

This gives us for $\tan\alpha$ using (IV. 4,3)

$$\tan\alpha = \frac{\Sigma_i \, z_i' \, \vartheta_i}{\rho \, \Sigma_i \, \vartheta_i^2} \qquad \text{(IV. 4,8)}$$

where Σ_i is taken over all points found in space.

5. Errors on first approximation

We can estimate errors on the parameters of the track in first approximation. These will be given as results in the case that the next step in fitting a helix (IV. 6) to the track does not give satisfactory results.

We can calculate variances $\sigma^2_{\lambda_1}, \sigma^2_{\lambda_2}$ and co-variance $\sigma_{\lambda_1,\lambda_2}$ upon λ_1, λ_2 the two parameters of the fitted circle from which we deduced ρ and β. Since ρ and β are functions $f(\lambda_1, \lambda_2)$ we can use the relation

$$\sigma^2_f = \left(\frac{\partial f}{\partial \lambda_1}\right)^2 \sigma^2_{\lambda_1} + \left(\frac{\partial f}{\partial \lambda_2}\right)^2 \sigma^2_{\lambda_2} + 2\,\frac{\partial f}{\partial \lambda_1} \cdot \frac{\partial f}{\partial \lambda_2}\,\sigma_{\lambda_1 \lambda_2}$$

and for co-variances

$$\sigma^2_{f_1 f_2} = \frac{\partial f_1}{\partial \lambda_1} \cdot \frac{\partial f_2}{\partial \lambda_1}\,\sigma^2_{\lambda_1} + \frac{\partial f_1}{\partial \lambda_2}\,\frac{\partial f_2}{\partial \lambda_1}\,\sigma^2_{\lambda_2} + \frac{\partial f_1}{\partial \lambda_1}\,\frac{\partial f_2}{\partial \lambda_2}\,\sigma_{\lambda_1\lambda_2}$$

$$+ \frac{\partial f_1}{\partial \lambda_2} \cdot \frac{\partial f_2}{\partial \lambda_1}\,\sigma_{\lambda_1\lambda_2}$$

Using these formulas upon (IV. 4,4) and (IV. 4,5), we obtain

$$\Delta\rho = \sigma_\rho = \frac{1}{2\rho}\left[\lambda_1^2\,\sigma^2_{\lambda_1} + \lambda_2^2\,\sigma^2_{\lambda_2} + 2\lambda_1\lambda_2\,\sigma_{\lambda_1\lambda_2}\right]^{\frac{1}{2}}$$

$$\Delta\beta = \sigma_\beta = \frac{1}{4\rho^2}\left[\lambda_1^2\,\sigma^2_{\lambda_2} + \lambda_2^2\,\sigma^2_{\lambda_1} - 2\lambda_1\lambda_2\,\sigma_{\lambda_1\lambda_2}\right]^{\frac{1}{2}}$$

$$C_{\rho,\beta} = \sigma_{\rho\beta} = \frac{1}{16\rho^3}\left(-\lambda_1\lambda_2\sigma^2_{\lambda_1} + (\lambda_1^2 - \lambda_2^2)\,\sigma_{\lambda_1\lambda_2} + \lambda_1\lambda_2\sigma^2_{\lambda_2}\right)$$

For $\Delta \tan\alpha$ we use

$$\Delta \tan\alpha = \sqrt{\frac{\Sigma(z_i - \rho\vartheta_i\ \mathrm{tg}\alpha_i)^2}{\rho^2\Sigma\vartheta_i^2\ (N-1)}}$$

6. Final least squares fit of the helix

We found an approximate value for ρ , tgα , β , A, B, C. For each measurement we have also its reconstruction line (IV. 2). The final fit consists in finding small corrections to the coefficients of the helix so that the equations (IV. 2,1 and IV. 2,2) and the equations of the helix (IV. 4, 1 to 3) are simultaneously satisfied. The method is described in CERN 60-33 (section 5.4). To apply this method we have to associate an azimuthal angle ϑ_i with each measurement i.

ϑ_i is given by

$$\vartheta_i = \arctan \frac{y_i - (B - \rho \sin\beta)}{x_i - (A - \rho \cos\beta)} - \beta \qquad \text{(IV. 6,1)}$$

in which ρ , β , A, B are the results from the first approximation. x_i, y_i are found with formulas (IV. 2,1 and 2) in which we start for the first measurement with $z_1 = C$. So we find ϑ_i with (IV. 6,1) and hence a better z_i with (IV. 4,3), and thus a better ϑ_i. We are thus doing the process twice, the first time using the z value of the previous measurement.

This last fit of the helix is an iterative process which converges in normal cases. However, if this process does not converge, we use the first approximation (Section IV. 4) as a satisfactory result.

Straight tracks

The assumption is made that a track which should be reconstructed as straight, has for its second label a letter which is further in the alphabet than a letter given in TITLE 1.

For these tracks the radius ρ is fixed to a large value which is given in TITLE 1.

The calculations followed are the same as those for curved tracks except for the following :

1. for finding view β (Section IV. 3), we take for ϕ

$$\phi = \frac{\Sigma Y_i}{\Sigma X_i}$$

2. for the first approximation we have

$$\beta = - \frac{\Sigma (x_i - A)}{\Sigma (y_i - B)}$$

and $$\vartheta_i = \frac{\sqrt{(x_i - A)^2 + (y_i - B)^2}}{\rho}$$

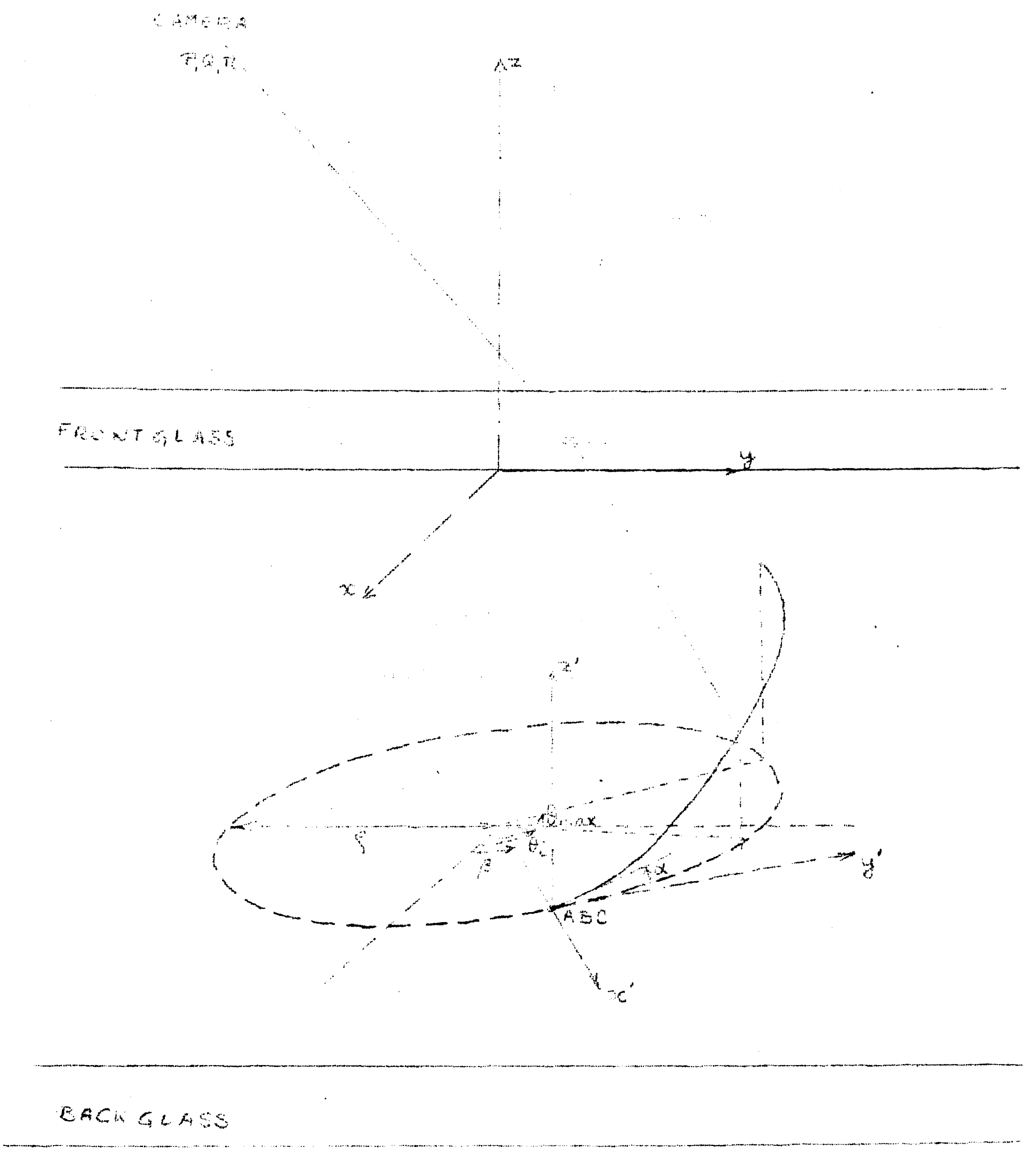
3. in the least squares fit (Section IV. 6), the corrections to β, $tg\alpha$, A, B, C are found in the same way as for curved tracks, but $\Delta\rho$ is not found, since ρ is fixed to a constant value.

V. Final remarks

1. About errors calculated in THRESH

The errors given (for the parameters of the helices and points are the standard errors and co-variances resulting from the least squares method as described in (App. III of ref. 6). Work is being done to find an estimate of the external errors (ref. 7 and 8).

FIG. 2



APPENDIX A.

Method of near corresponding points

This method is used to find the co-ordinates $(x_i\ y_i\ z_i)$ for the measurements on a view α of a track.

Given the measurement (X^α, Y^α) defining F_x^α, G_x^α, F_y^α, G_y^α in the equations of the reconstruction line

$$\begin{aligned} x &= F_x^\alpha z + G_x^\alpha \\ y &= F_y^\alpha z + G_y^\alpha \end{aligned} \qquad (5)$$

The method consists in finding by interpolation between all the values

$F_{x_i}^\beta$, $G_{x_i}^\beta$, $F_{y_i}^\beta$, $G_{y_i}^\beta$ for the measurements in an other view β,

a set of values F_x^β, G_x^β, F_y^β, G_y^β such that

$$\begin{aligned} x &= F_x^\beta z + G_x^\beta \\ y &= F_y^\beta z + G_y^\beta \end{aligned} \qquad (6)$$

intersects the line (5) in space.

The condition for intersection of lines (5) and (6) can be written as

$$\phi \equiv \begin{vmatrix} F_x^\alpha - F_x^\beta & F_y^\alpha - F_y^\beta \\ G_x^\alpha - G_x^\beta & G_y^\alpha - G_y^\beta \end{vmatrix} = 0 \qquad (7)$$

The function ϕ is evaluated for the measurements on view β, in succesion until there is a change in sign between two successive measurements $i, i + 1$. A linear variation of F's and G's is assumed between the two measurements $i, i + 1$. Thus we can write

$$F_x^\beta = F_{x_i}^\beta + \lambda (F_{x_{i+1}}^\beta - F_{x_i}^\beta)$$ and similarly for F_y^β, G_x^β, G_y^β.

Hence we can write (7) as

$$\phi (\lambda) = 0$$

We find λ which satisfies this equation by successive approximations, starting with $\lambda_o = 0$ and $\lambda_1 = 1$. We get a better value λ_2

$$\lambda_2 = \frac{\lambda_0 \phi (\lambda_1) - \lambda_1 \phi (\lambda_0)}{\phi (\lambda_1) - \phi (\lambda_0)}$$

which replaces λ_0 or λ_1, depending on whether $\phi(\lambda_2)$ has the same sign as $\phi(\lambda_0)$ or $\phi(\lambda_1)$. Having found λ, F_x^β, G_x^β, F_y^β, G_y^β are calculated and hence, from eq.(5)

$$z = - \frac{G_x^\alpha - G_x^\beta}{F_x^\alpha - F_x^\beta} = - \frac{G_y^\alpha - G_y^\beta}{F_y^\alpha - F_y^\beta} \tag{8}$$

One of the fractions in eq.(8) can take the form $(\frac{0}{0})$, entirely due to choice of co-ordinate axis. In this case z is taken as the value of the other fraction of eq.(8). Finally we find x and y by the formulas (5).

This method is also used to find the co-ordinates of the beginning of a track as mentioned in Section III.

APPENDIX B

Details on the existing programme in March 1963

I give here a short description of what each subroutine does :

Main programme : contains print instructions at beginning of run reading call cards and select cards.

NOF : is a FAP routine which reads into an array NO (18) all the possible combinations in groups of 2 and 3 of the integers 1, 2, 3, 4. This to be able to retry reconstruction of points with different views.

EVENT 2 : is the reading routine for an event.

GI 2 : reads into store the TITLE 1 required for the event.

TITRE : does calculations I, to set up a reference system.

GEOM 2 : does calculations II.

MC : is called by different routines to construct the normal system of linear equations in the method of least squares.

BRER : is a routine to solve a system of linear equations.

ERREUR : finds the error matrix of the unknowns of the linear system.

GEOM C : reconstructs the points in space, if at least 2 views are given.

FGXFGY : finds the coefficients of the reconstruction lines (III, IV.2).

GEOM D : does calculations IV.1.

ARRAN : does calculation IV.1, a.

GEOM E : finds an approximation for the apex of a track when it was not found by GEOM C.

POICOS : finds the co-ordinates of a point in space, knowing two near corresponding measurements on View β.

LAMB 12 : finds the parameters λ_1, λ_2 of the circle IV.3, 1.

GEOM G : finds the near corresponding measurements on View β.

GEOM H : finds IV.6.1.

LSHELX : does the final least squares helix fit.

GEOM PR : is the BCD output routine.

SHUNT : places the results in order to go ingo Grind.

OP : FAP output routine

entries (INTOP
(OPCHK
(OP

MXEQU : an entry into MXPACK : a FAP programme handling with matrices.
This entry is to solve a linear system.

Faults and rejections

		Fault number
A whole event will only be rejected if :		
1)	no call cards are given for the experiment	printed
2)	the required TITLE 1 is not on the General data tape	printed
3)	the output tape of REAP is bad	printed: CHECK SUM ERROR OR REDUNDANCES
4)	less than two views are available to do the reconstruction - a view can be rejected if :	
	a) not enough (< 3) fiducials are measured	1
	b) a fiducial mark is badly measured	2
A labelled point can have :		
1)	not enough measurements	3
2)	not enough good views for the point	4
3)	errors on the co-ordinates too large	17

A track will be reconstructed if at least two good views are available.

A view can be rejected for different reasons :		
1)	reasons giving fault 1 or 2	15
2)	more than 50 points measured on the track	6
3)	less than 3 points " " " "	9
4)	less than 3 points after rejecting a point (IV.1, b)	9

		Fault number
5)	more than 1 point out of tolerance (IV.1. b)	11
6)	the distance of the apex to the circle (IV.1.1) is greater than the tolerance, and more than one view is given for the apex	10
7)	the radius of circle (IV.1.1) is < 0	24

When a track is not reconstructed its parameters are put to zero, and its radius put to a negative big number (10 x max. meas. radius in TITLE 1).

R E F E R E N C E S

1. DD/IED/61/37 — New IEP programmes with library facilities. — G.R. Macleod

2. CERN 60-11 — Input programme for measurements of track chamber photographs. — G.R. Macleod

3. DD/EXP/63/1 — The tape routines for THRESH, GRIND and COOK. — R. Lorkin

4. Programme GAPZ, Saclay

5. GRIND manual

6. CERN 60-33 — A programme for the geometrical reconstruction of curved tracks in a bubble chamber. — W.G. Moorhead

7. DD/IEP/61/34 — Tentative to define a "good measurement" and realistic error matrix. — E. Fett, L. Montanet

8. DD/IEP/61/30 — Note on errors on reconstructed tracks in bubble chambers. — W.G. Moorhead

DISCUSSION FOLLOWING THE TALK OF MISS A. M. CNOPS

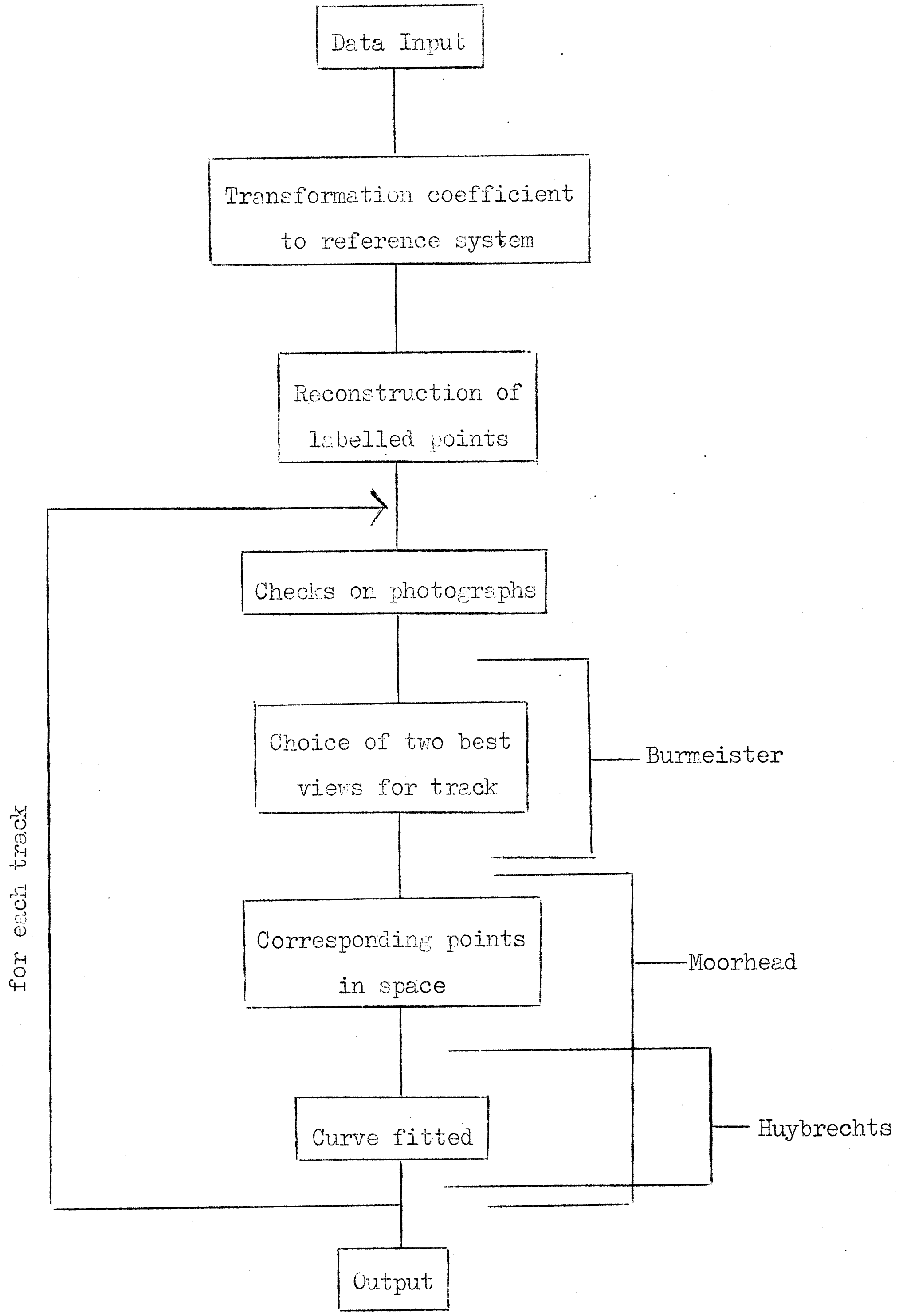
Werbrouck: What is the approximate reconstruction time in THRESH for a track about 50 cm long and measured on 3 views?

Cnops: One event consisting of 4 - 5 tracks uses 20 - 30 seconds of IBM 709 time, including input and output. The greatest part of this time is taken by the reconstruction.

Glasser: What is the main reason why tracks fail to converge in THRESH?

Cnops: The main reason is because the first approximation is bad, and this could be due to the wrong choice of views.

Goldschmidt-Clermont: For about 50% of the cases where a track does not converge, we seem to have a good first approximation.


Data Input
Transformation coefficient to reference system
Reconstruction of labelled points
Checks on photographs
Choice of two best views for track
Corresponding points in space
Curve fitted
Output
for each track
Burmeister
Moorhead
Huybrechts

	IMPROVEMENTS TO THRESH FOR HEAVY LIQUID				PROGRAMMES OF OTHER LABORATORIES			
	THRESH	HUYBRECHTS	MOORHEAD	BURMEISTER	ECOLE POLYTECHNIQUE	MILAN	RUTHERFORD	TURIN
Input	REAP output (BCD) camera position fiducials - refract. indices etc.				$<$10 points/track/view 2 views/track mass, direction, etc.	Mangiaspago output BCD	Optical constants fiducial positions on film. Track co-ordinates vertex co-ordinates fiducial co-ordinates for each event 2 or 3 views.	IBM cards from digitalized mangiaspago or projector. Points every 1-2 cm in all 3 views
Ref. system transformation coeff.	apparent fiducial marks (minimum 3)				app. fid. (2 fid. meas.)		Fit made to true fiducial positions on film. 6 coefficients found for each view. Min. of 2 fiducials on a view, max of 10	One pair of apparent fiducial marks whose positions are calculated at the beginning of each run.
Reconstruction of apices	with measurements on minimum of 2 views						With measurements from 2 or three views	As corresponding points in two combinations of principal view with auxiliary
Tracks : checks of measurements	fits circle in each view, rejects bad measurements				fits to parabola on front window - rejects bad measurements	Reconstruction as in THRESH. Possibility of 2-point tracks	Fits circle or parabola on front window, rejects bad measurements indicating which they were	Compatibility between the two views
choice of views	1° pivotal 2° antipivotal (for each meas. if necessary)			for each measurement choice of 2 best views	by hand - principal, secondary.		Mainview selected on length and stereo criterion	Principal view chosen for each point as that view opposite the x axis most nearly parallel to the segment under consideration as seen in a control view x axes correct optic axes
points in space	corresponding with measurements in pivotal view - Method of near corresponding points (linear interpolation)		method of near corresp. points second order interpolation		corresponding points on principal view - reconstitute points in space		Reconstruct points on mainview by method of finding corresponding points, weight the two sub-views to obtain best value	quadratic interpolation if 3 or more points are measured along the track
parameters of curve	helix-fit to points in space corrections to parameters, by least squares method, using measurements of all views.	no curve fitting. Max. likelihood estimation of parameters - curvature obtained from a weighted average of angles between successive cords.	optim. length parabola fitting		project on front window fit parabola → curvature in middle with mass hypothesis → momenta at end - business for stopping tracks optim. length - azimuth with end point closest to optim. length id.f.dip.		Fit with parabola or straight line to optimum length of curve for azimuth and dip separately, and with three different mass assignments for the track (K, π, P)	no curvature although the points are suitable to enter a curvature calculation. The length of the track corrected for measurement errors
kinks	track measured in several parts, each being reconstructed separately - combination of parts done in GRIND	The program detects kinks				Track measured in parts. Combination done by GAP990	Kinks are measured as such and program takes momentum from range or from section with max. length. Produces γ ray angles by weighting angles obtained from electron tracks	The program follows kinks small enough that the range still has significance afterwards.
output	binary tape	id THRESH-			cards) p, $\lambda\phi$, --- print)	BCD tape → cards and print	binary tape and paper print out	printed output one card per event used for making histograms scatter diagrams, checking weights and calculating polarization.
	in production	working, but not yet connected to THRESH	development	working but not yet connected with THRESH	in production		in production	

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