THE HOLMES PROJECT

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1. INTRODUCTION

HOLMES is a working prototype of a scanning and measuring machine for HOBC holograms. The machine is connected via CAMAC electronics, a MIK-11 microcomputer, and a serial link to a VAX computer. The scanning process is based on the use of TV displays.

We have made extensive use of the existing film-measuring machine spiral reader (SR) and its electronics, which have been out of use for two years. To the existing x-y stages of the SR we added an independent, lightweight, ballscrew-driven stage for z movement. The incremental encoders on the three stages have least counts of 2 μm in the x and y, and 4 μm in the z direction. Stage movements are controlled by means of a track ball for x and y, and by a wheel for z. Maximum travel time from one point on the picture to any other is 2 s.

The essential features of HOLMES are outlined in Fig. 1. To scan HOBC in-line holograms conveniently we need a choice of different magnifications of the reconstructed image, as has been demonstrated already on a series of NA16 images shown at the Rutherford meeting in January 1981. For the general survey and scanning purpose as well as frame number reading we use normal high-resolution 1 in. TV cameras. There is a particular need for an anamorphic display which opens up the particle jet image to an aspect ratio of 1:4. Furthermore, we use a high-magnification display for precise positioning. The general arrangement of these displays around the operator is shown in Fig. 2.

Since there is not much space available (90 mm) between the film clamp and the reconstructed image, we use a transfer lens (Componon 180 mm, f:5.6) to situate the image plane at a convenient place, where there is ample space to locate beam splitters, spatial filter wires, the cursor illumination system, and the TV cameras.

The operation of HOLMES is straightforward. We move the hologram in the x and y directions, but for movement in the z direction we move the linear z stage with its two-mirror set to bring planes at different depths in the bubble chamber to focus in the transferred image plane.

The greater part of the parallel laser light illuminating the hologram is still "unused" by the in-line hologram and as such forms a useless background illumination behind the image (see dotted lines in Fig. 1). This parallel light is concentrated by the transfer lens at its focal point and may be stopped there by a blackened needle or a similar beam stopper, acting as a spatial filter.

2. CAMERAS AND MONITORS

Camera A (Bosch TYK9A) shows an area of Lx = 7.2 mm × Ly = 10 mm on the film as well as in the space of the reconstructed image; x is parallel to the beam direction. Camera A is used by the operator

a) to stop the film at the right position and to show the picture number,

b) to find and roughly centre the fiducials,

c) to find and roughly centre the predicted beam track,

d) to investigate all secondary tracks at large angles from the beam direction,

e) to find secondary vertices at large angles (Fig. 3a),

f) to show highly ionizing tracks if spatial filtering is used for camera B (see below).

The spread in y of 11 mm is just sufficient to show the last three digits of the picture number without moving the picture. When showing the picture number the x-y stage is driven to the expected picture number position and the camera is focused by the z stage onto the film plane which is illuminated by the laser.

The camera is equipped with a vidicon and has an automatic gain control (AGC). It is connected to a standard TV monitor (monitor 1).

Camera B (Hamamatsu C1000-16) was specially modified by Hamamatsu to provide an anamorphic display of the picture. The magnification perpendicular to the beam direction (y) is about five times larger than along the beam (x).

The camera displays an area of L_x = 11 mm × L_y = 2.8 mm in the real image. It is used

a) to resolve the secondary tracks in the jet (Fig. 3b),

b) to detect and verify secondary vertices.

It is practically impossible to disentangle the tracks in the jet using camera A rather than camera B (compare Figs. 3a with 3b and 4b with 4d).

Owing to the small visible area in y (L_y = 2.8 mm) and the anamorphism (which cannot be modified) the camera can neither be used to read the picture number nor to investigate easily tracks at large angles (compare Figs. 3a and 3b). If a spatial filter is used, highly ionizing tracks become invisible. Hence the necessity of using the two cameras A and B.

Since camera B has no AGC the operator is provided with a control of laser intensity in case the film density varies.

Camera B can be connected by operator control either to the normal TV monitor or to the graphics monitor. A small mirror on the table in front of the monitor allows inspection of the monitor screen at a shallow angle as can be done when scanning on a table. For small kinks this turned out to be helpful. We will investigate whether a monitor screen which is not perpendicular to the view of the operator is advantageous.

Camera C (Bosch TYK9A) shows an area of L_x = 0.8 mm × L_y = 1.3 mm. It is used

a) to focus (z measurements),

b) to measure x and y precisely,

c) to magnify the interaction region,

d) to resolve close tracks (Fig. 3c).

This camera has an AGC and can be connected by operator control to monitor 1 or 2.

3. SPATIAL FILTERING

As described above, a spatial filter has been used successfully. It consists of a straight wire passing in the y direction through the focus of the transfer lens; compare Figs. 4a and 4c with 4b and 4d. It has the following advantages:

a) The background is more uniform.

b) From large objects the edges only are visible.

c) The signal-to-noise ratio is much improved.

d) By use of the wire instead of a point, linear structures in the x direction are eliminated (scratches on film, etc.).

e) The focusing precision is higher (see below).

f) The smaller focal depth helps in detecting kinks in z, which are not visible in the x-y plane.

g) Highly ionizing tracks, especially in the beam direction, are filtered out.

h) The change in density at the edge of the picture gives problems when inspecting the TV image, as one part of the image is too light and the other too dark. The spatial filter solves this problem (otherwise a mask must be used which needs a precise film stop).

It has the following disadvantages:

a) A higher laser intensity is needed.

b) The focal depth is reduced so that one must scan in different z planes.

c) The image of the fiducials is of less good quality.

d) The picture number is not visible.

The resolution on camera B seems to be as good as without the spatial filter. Spatial filtering for camera C will soon be tried.

A spatial filter which can be moved in and out by the operator might be more useful.

4. z MEASUREMENT

The focusing (z) is done purely manually. Table 1 shows the r.m.s. of 22 z measurements of the same bubble string for the three cameras with and without the spatial filter, which cannot yet be used for camera C because of insufficient laser intensity. The measurement of the focal depth being very subjective is only qualitative.

Table 1

Camera	A	A	B	B	C
Spatial filter	No	Yes	No	Yes	No
Lx (mm)	7.5	7.5	12.5	12.5	0.8
Ly (mm)	11	11	3	3	1.3
r.m.s. (μm)	700	400	400	200	70
Max. error (μm)	1400	800	800	480	160
Focal depth (mm)	3	1.5	2	1	1

The relatively high precision of positioning in z obtained with camera C compared to that with cameras A and B justifies its use.

However, the precision in z is still much worse than in x or y (some microns). If the light cone of the individual bubbles is not parallel to the z axis, a condition which might be produced by a wrong adjustment of the z stage, an error in x and y will result from the difficulty of focusing. The same is true if the film is not perpendicular to the laser beam when exposing the hologram. Illumination of the bubble chamber by a convergent laser beam produces the same effect if the light is not made parallel before reaching the film. This may necessitate a different coordinate system (R, θ, ϕ) for the software or maybe even for the stage movements.

Owing to the big difference in precision between x, y, and z, all errors, fit parameters, offset parameters, etc., are calculated separately for x, y, and z.

5. VERIFICATION OF SECONDARY VERTICES

Many secondary vertices are not clearly visible and outgoing secondary tracks must often be checked. To establish whether they originate from the primary or secondary vertex, two methods are possible:

i) By measuring one point on the track a line in space between the track point and one of the vertices is calculated. Visual inspection (see below) then shows whether the real track and the calculated line coincide.

ii) By measuring two points on the track portion behind the suspected kink the calculated offset parameter may be used for a decision or one may follow the line backwards to check whether it passes through the vertex. In this way the position of very small kinks may be found.

Two methods are available to check whether the track and the calculated line coincide:

a) A graphic line is overlaid onto the video image (Fig. 5a). This method works only if the kinks are visible in the x-y projection.

   Only the overlay of a straight line through the centre of the monitor is needed. The magnification of the video image and the graphic picture need not be equal! (if no graphic monitor exists, one may try to overlay an optically produced rotatable line via a semi-transparent mirror onto the monitor).

b) A mechanical movement along the calculated line allows a check in space. It is more precise as it avoids distortions of the optical system and the TV cameras. However, it is much more time consuming than method (a).

In practice the movement along the line is done by reading every 20 ms the desired movement from one direction (x) of a track ball. From this the appropriate movements of the three stages x, y, z are calculated and executed.

The speed and ease of method (a) is improved in the following way: one cross which is fixed in the middle of the screen indicates the measuring position. A second cross is moved instantaneously with the position of the x-y stage (properly scaled down). It indicates automatically the direction and the distance to the vertex (Fig. 5b). If a track is centred on the middle cross, it originates from the vertex only if the moving cross is also centred on the track. Moreover, the vertex may always be recovered if one moves the second to the first cross. On the vertex itself the crosses are superimposed.

6. SCANNING PROCEDURES

i) Manual measurement of one fiducial (the predicted track is shown automatically).

ii) Search for and measurement of a beam track (only a movement along the known beam direction is possible).

iii) The vertex is found.

iv) The vertex is measured.

v) Search for secondary vertices. Several methods can be used:

a) Continue movement in beam direction for optical inspection. The width (y) of the area shown on camera B is larger than the "charm box". If spatial filtering is used this must be repeated for different z values.

b) Check any track on the graphic monitor to see whether it coincides with the two crosses.

c) Check any track in space by mechanical movement along line.

vi) If a candidate is found it may turn out to be necessary to check it carefully by the mechanical movement along the predicted line. By using two points per track the kink point or secondary vertex may be found.

vii) If one candidate is found a more careful search for a second one may be necessary [points (vb) or (vc)].

viii) The relevant tracks can be measured with many points. Kinks, etc., can be found by investigating the residuals to a straight line fit.

The time to scan an event depends heavily on the methods used; this means whether a visual inspection only is performed [continue with (vi) after (va)] or whether the much more complicated methods (vb) and/or (vc) are used too.

The boundaries of the scanning volume in the x-y plane are indicated on the graph monitor as normally no fiducials to define the scanning volume are visible.

7. FUTURE DEVELOPMENT PROGRAMME

- Improvement of adjustment.
- Study of spatial filtering.
- Continuation of scanning (so far 236 pictures with 95 events have been scanned).
- Provision of a cursor on all monitors.
- Study of double beam holography.
- New (cheaper) graphical overlay.
- Study of video signal treatment.
- Automatic focusing.
- Holography of big chambers (BEBC).

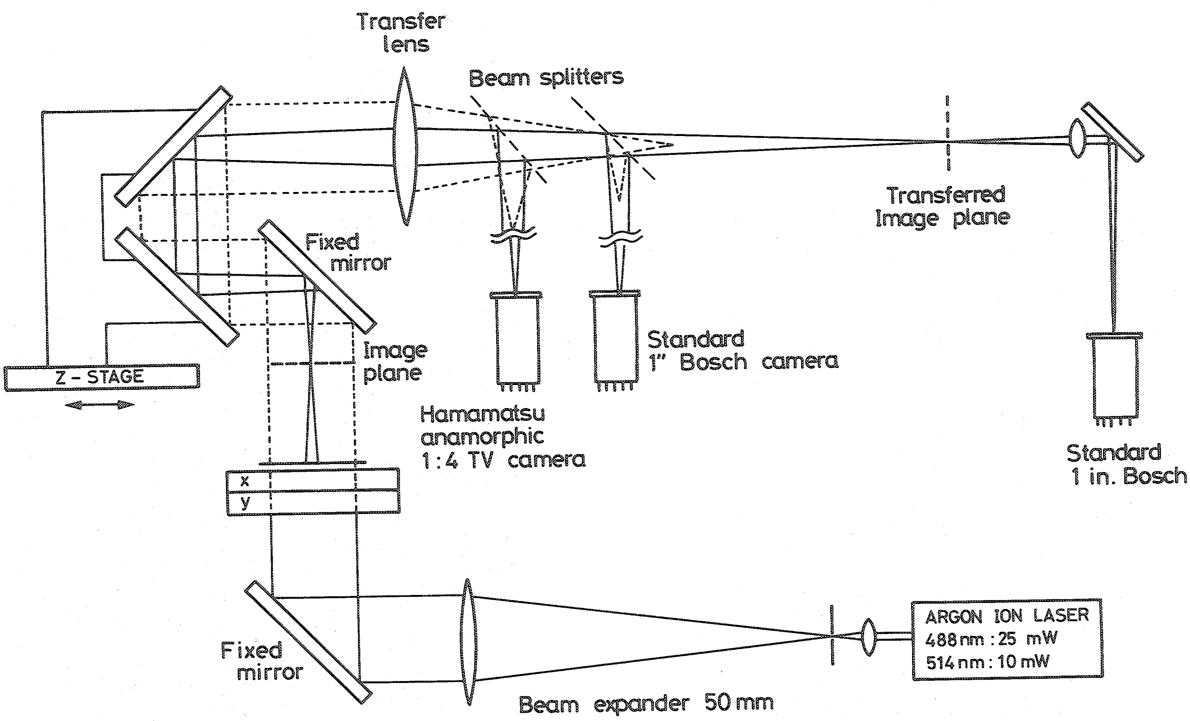


Fig. 1 Outline of the essential features of the HOLMES prototype of a scanning and measuring machine for in-line holograms

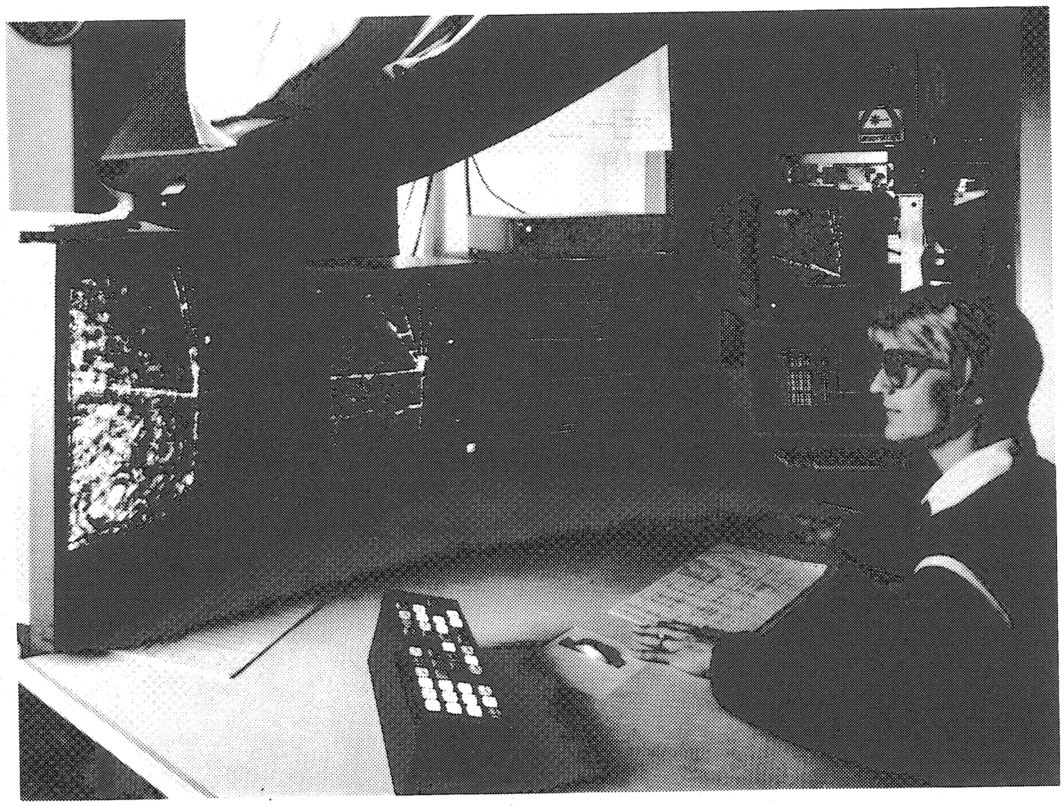
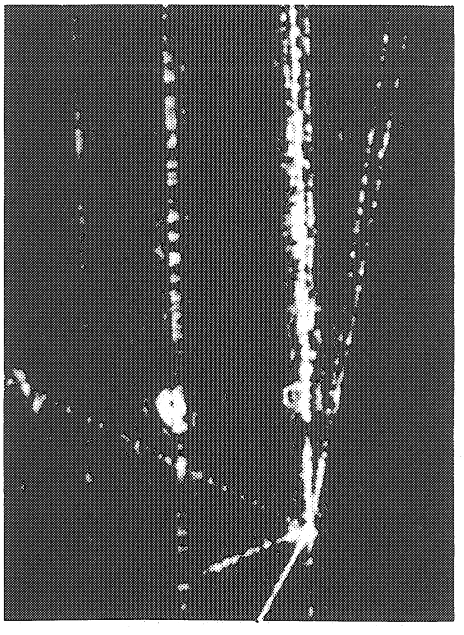
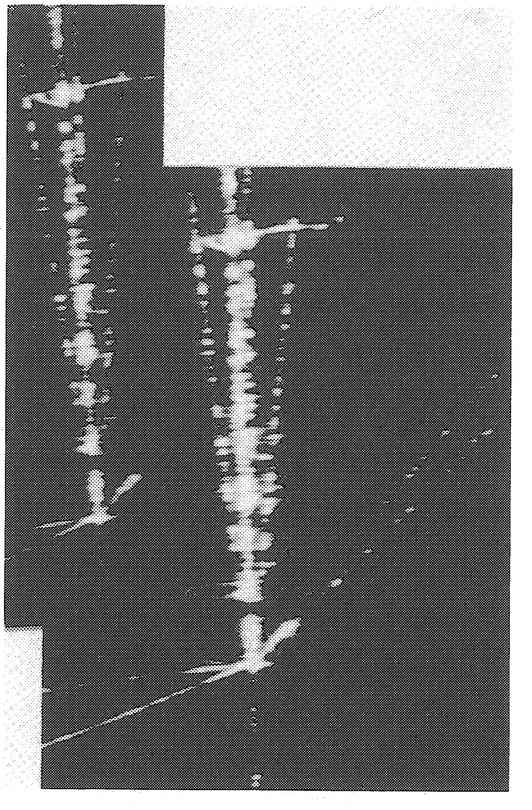


Fig. 2 Arrangement of the general purpose, anamorphic and graphics monitors, computer terminal, x-y track ball, z wheel, and machine control keyboard in front of the operator



a)



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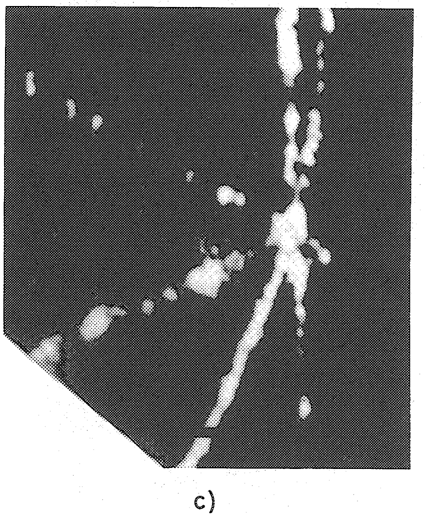
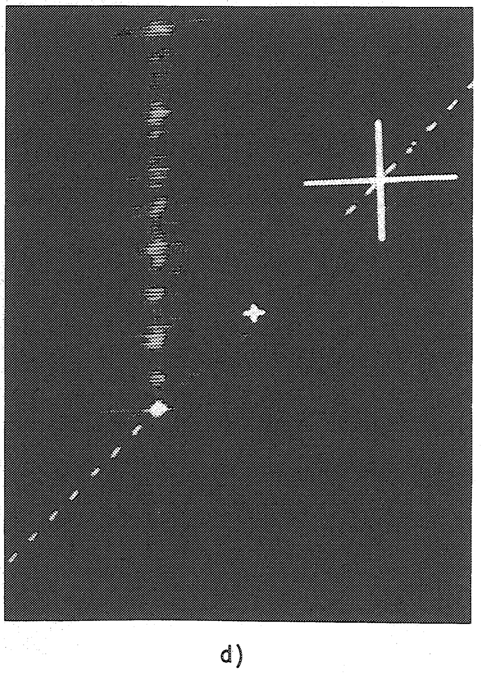
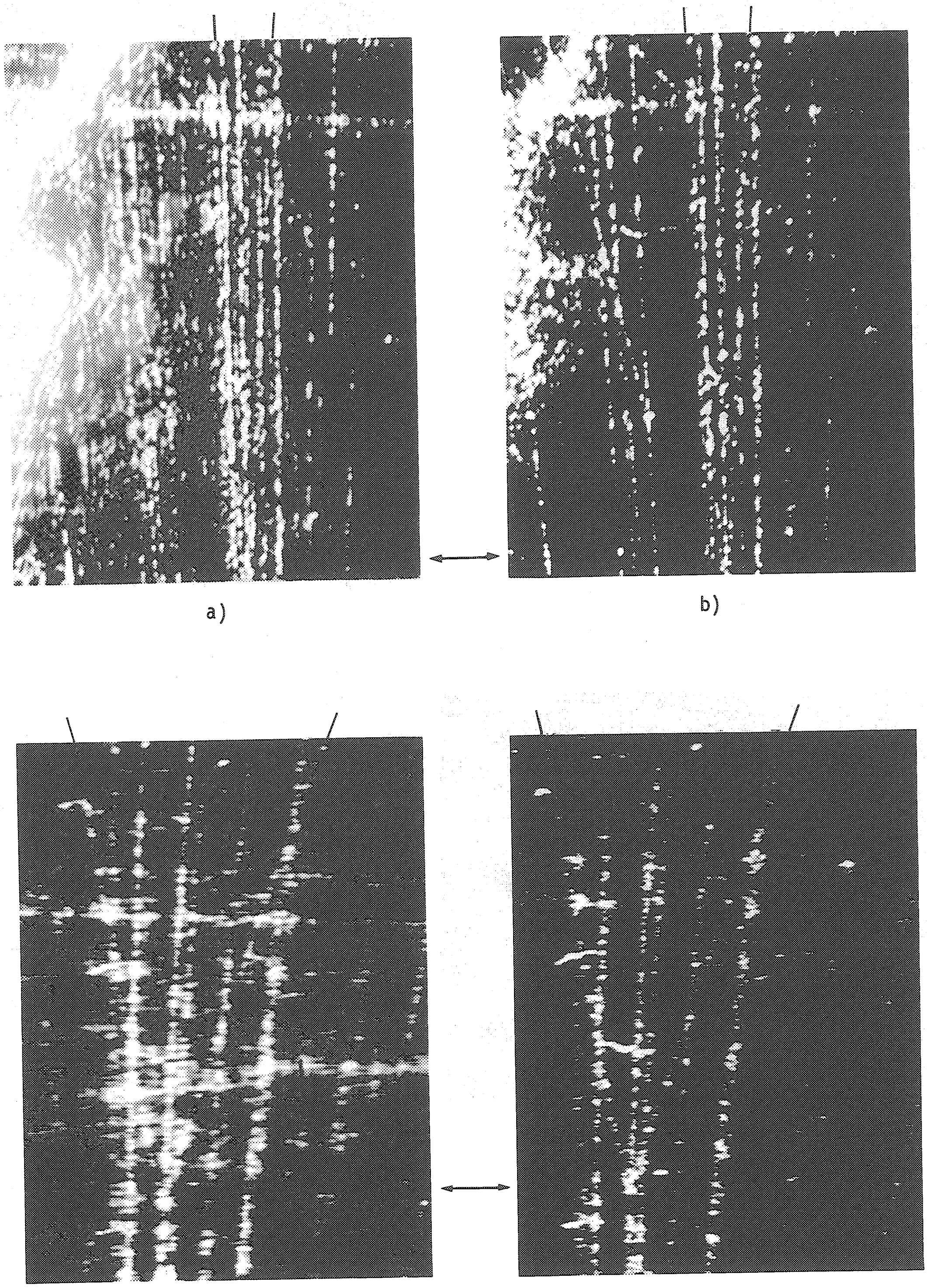


c)



d)

Fig. 3 The same event is seen (a) with camera A, (b) with camera B, and (c) with camera C connected to the normal monitor, while in (d) the same event is seen with camera B connected to the graphical monitor. Spatial filtering is not used in any of the four pictures.



a) b)

c) d)

Fig. 4 The same V^0 is seen (a) and (b) on camera A, and (c) and (d) on camera B. The position of the decay point is indicated by an arrow. The spatial filter is not used in (a) and (c). In (b) and (d) it is used.

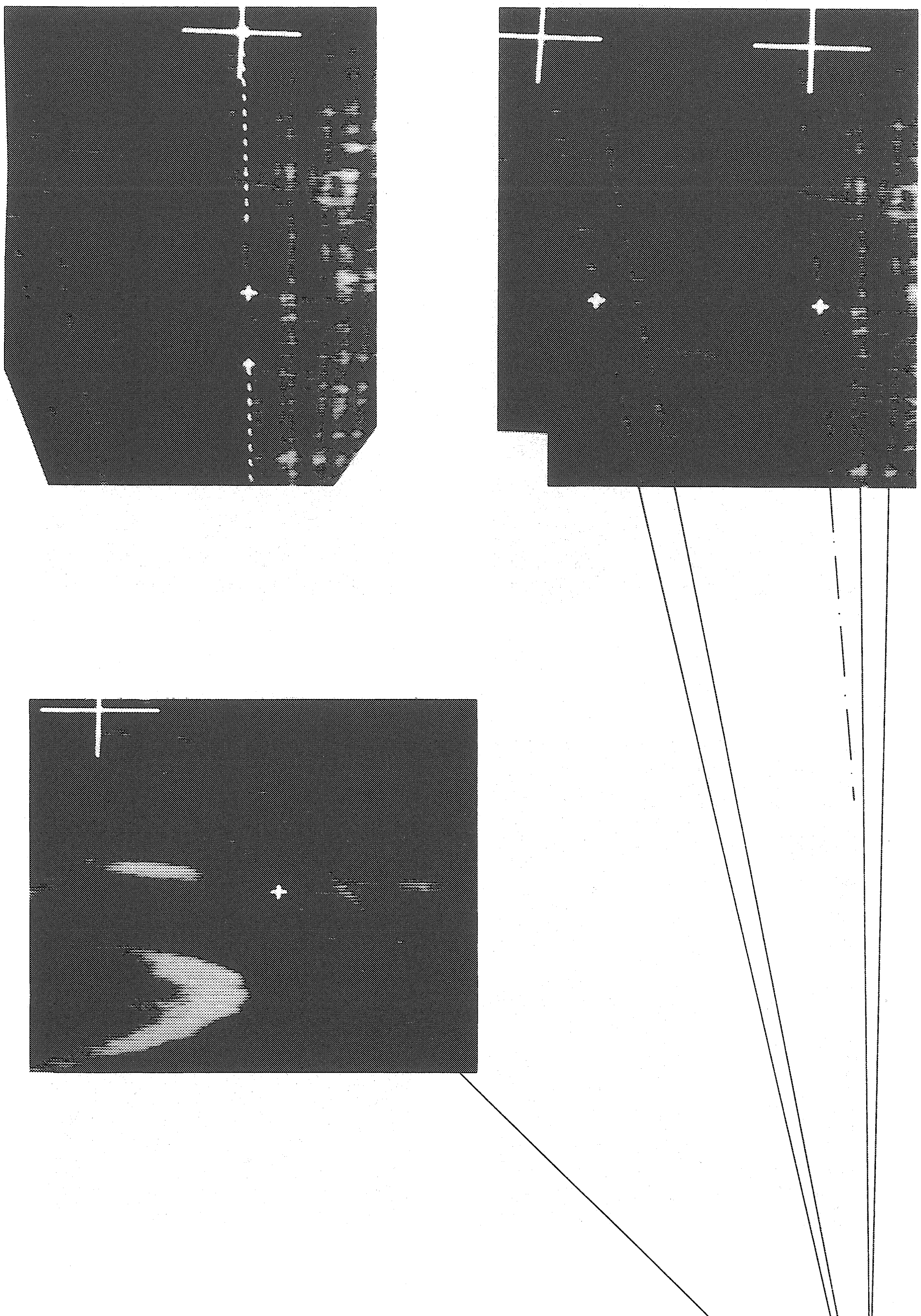


Fig. 5 a) Graphic overlay of a line onto a track which does not originate from the primary vertex. b) By use of the fixed small cross and the moving big cross, the origin of secondary tracks is checked. All pictures are taken using camera B without spatial filter.