CERN-DATA HANDLING DIVISION
DD-74-1
CERN D.PH.II/INST. 74-1
24.1.1974

TRACK DETECTION IN ERASME FOR THE FILM FROM THE NEW GENERATION OF BUBBLE CHAMBERS

H. Anders and L. Sohet
CERN, Geneva

ABSTRACT

The present state of the video signal processing of ERASME is described. Automatic gain control has been introduced to cope with large and abrupt changes of background density. Practical results on photos of BEBC, Mirabelle and Hybuc are shown. Measurements of signal-to-noise ratio are described.

Enlarged version of the talk given at the HPD Collaboration meeting held at Bologna on 21 September, 1973.

HA/mk

CONTENTS

1. INTRODUCTION

As in HPD's, ERASME makes use of a flying spot of light to scan photos. From the point of view of the track detection system, it is of no great importance whether this spot is generated "mechanically" or on the surface of a cathode ray tube. Furthermore the ability of a CRT system to select different parts of a photo at random and to change scan parameters very rapidly, only concerns the techniques used by the programs to isolate the images of tracks and fiducials from the background. For this reason all the illustrations in this paper, apart from one, are made using an HPD-type raster scan. Thus the same results can be expected on an HPD if the same technique of signal treatment is used.

2. PRINCIPLES OF THE VIDEO PROCESSING

The method of processing the photomultiplier signal is described in detail under ref. (1). For reasons which are explained below automatic gain control was introduced after that report was written.

In fig. 1, the block diagram of the video processing unit is shown. The circuit can be divided into 4 parts.

The first part would not be relevant for HPD. It serves to remove the particular errors introduced by the CRT: Light variation due to the grain structure of the phosphor and the afterglow distortion.

The second part limits the upper end of the frequency band by a $\sin^2$-filter and the lower end by the clamping procedure. At the output of this part the signal contains only those frequencies which contribute to the form of the track pulses, thus limiting the noise to a minimum.

Fig. 2 shows the principle of the clamping circuit which can be considered as a non-linear low-pass filter.

The signal containing positive going track pulses is coupled to point A through the capacity C. The clamping diode D suppresses negative going changes of the signal. As long as the signal remains lower than the discriminator threshold of the clamping stage, switch S_1 is closed. This causes point A to be held at the clamping potential even during slow positive changes caused by the film background.

Fast changes of the signal in positive direction will cause the threshold to be passed and therefore the switch S_1 to open. From now on, the coupling time constant is so big that no signal distortion occurs. Only when the signal returns below the threshold will the clamping resume.

There is another switch S_2 which forces point A to return to the clamping level if the signal remains above the threshold for longer than could be caused by a track signal. In particular, this is the case if the film background has changed in a step to a smaller density.

In fig. 3 the effect of the signal clamping is shown. The first line represents the original PM signal. On the second line, the background variations have been removed. The switching of the time constant occurs at the voltage V_c, which is fixed. It is adjusted to be somewhat below the peak film noise level in order to ensure that even the smallest track pulses are not deformed.

The third part of the video processor performs the proper track detection. Its principle is indicated on the third line of fig. 3. A simple threshold detection is used. This threshold V_d is adjustable either manually or under computer control.

The utilization of two different discriminator levels, one for clamping and the other one for track detection has considerably improved the precision and stability of track detection.

3. AUTOMATIC GAIN CONTROL

3.1. Why automatic gain control?

The circuit described up to now can cope with a certain change of background density and a contrast of the track images as low as 0.3. Originally, it was expected that the background density of BEBC would change only between 0.7 and 1.0 which corresponds to a change of transparency of 2.

In this case it would have been sufficient to slightly change the discriminator threshold in order to detect all pulses. However, at present, background variations of BEBC photos are between 0.7 and 1.5, and sometimes, even 1.7. This is equivalent to a variation of transparency by a factor of up to 10. Also the contrast of the tracks is very variable and is sometimes smaller than 0.3.

If one assumes constant contrast of the tracks the amplitude of the pulses thus varies by a factor of 10. This led to the introduction of automatic gain control in addition to the adjustable discriminator threshold as part four of the circuit.

In the case of constant contrast all track pulses can be brought to the same amplitude irrespective of background variations, by controlling the gain in such a way that the DC-level of the background remains constant.

3.2 Method of automatic gain control

The gain control is performed in the photomultiplier. This has the advantage of drawing always about the same signal current from the PM anode. This avoids sending an insufficient signal to the amplifier, or overloading the PM anode in the extreme cases of low and high film density. If a voltage, between the last dynode and the anode of the photomultiplier, as low as between +1 V and -1 V (EMI 9656A) is used, the gain alters by more than a factor of 10. This method of current distribution control was to our knowledge, proposed originally in our field by J. Rosenthal and M. Fiehrer in 1964 (ref. 2). It was recently taken up again by K. Wattenbach (ref. 3) for use in the spiral reader.

3.3. Automatic gain control and programmed discriminator threshold

Contrary to our simplifying assumption that the contrast of the tracks is constant in spite of changing background, it actually increases with increasing film density as indicated on fig. 4. For optimum results the characteristic of the automatic gain control should therefore be adapted to the "γ" of the film. Very satisfactory results were nevertheless achieved using the above techniques.

On BEBC photos there are areas where not only the contrast is low and variable but the tracks are partially masked by additional background images. This background is caused by spurious bubbles in areas where boiling occurs and where the scotchlite is covered with particles which reduce the light reflection. In such cases further improvement of track detection performance can be achieved by applying automatic gain control and control of the discriminator threshold simultaneously. As the locations of these areas are constant from one photo to another the control of the threshold can be programmed as a function of the position of the area being scanned.

4. PRACTICAL RESULTS

In the following, the quality of track detection on photos with considerably varying background density is demonstrated. The worst case at the present time (July 1973) is certainly BEBC. However, it is expected that the eveness of the background will improve*. Therefore this should only be considered as a test picture and not to be representative of the future quality. For comparison photos from Mirabelle and from the fast cycling bubble chamber HYBUC are shown.

First, the original photos are reproduced and then the display of the digitizings on the screen of a 611 storage scope. During the scan of one picture the discriminator level was kept constant and automatic gain control was operating. The discriminator level was not changed

---

* There is a considerable improvement in the photos of the November 73 run.

when a smaller area was re-scanned in order to generate an enlarged display. It should be remembered that ERASME has no store for the digitizings apart from a small buffer. In order to change magnification or position of the display a new scan has to be performed.

For easy comparison with HPD only normal (0°) and "abnormal" (90°) scans are used, with one exception on BEBC.

4.1 BEBC

Fig. 5 is the reproduction of the original. The figures indicate background density and the corresponding transmission factor.

Fig. 6 shows the digitizings of the entire photo. The resolution of the display scope is evidently insufficient.

In fig. 7 the lower part of the photo has been scanned and displayed in a larger scale. Attention should be drawn to the borders at which the background density jumps from 1.4 to 0.7, from 0.7 to 1.1 and from 1.1 to 0.7. There is either no, or only a very small "dead zone" where the tracks disappear.

In fig. 8, the center of fig. 7 is scanned horizontally. Only the track centres are displayed.

In fig. 9 the same area as on fig. 8 is scanned in "track following mode". In this case small scans are made perpendicular to the individual tracks. Both track centers and track width are displayed. The spacing of the scan lines is only 6 μm, i.e. individual scan lines are overlapping. This picture is an exception. It was introduced in order to demonstrate the flexibility of the CRT in performing scans in other than HPD mode. The advantages are obvious.

4.2 Mirabelle

For comparison, a Mirabelle picture was scanned. Here the background is relatively uniform. The contrast however is poor, and this picture is no longer representative as in the meantime the quality has improved.

Fig. 10 : Original photo.

Fig. 11 : Display of the digitizings of the whole photo. ERASME is covering an area about four times that of the photo.

Fig. 12 : Enlarged area. The area of the scan is marked on fig. 10 and 11.

4.3 HYBUC

This photo was chosen as an example of fast changing background density.

Fig. 13 : Original photo.

Fig. 14 : Display of the digitizings of several views.

Fig. 15 : Enlarged area, as indicated on fig. 13 and 14.

5. SIGNAL-TO-NOISE RATIO

To give an idea of the signal-to-noise ratio 32 track pulses, generated by repetitively scanning across the same track, are superimposed photographically in fig. 16. The same BEBC photo is used as on fig. 4. In this case the background density was 1.5 and the track contrast was 0.5. The peak-to-peak noise is approximately 10% of the pulse hight. The corresponding r.m.s.-value is 1.5-2%.

A more practical criterium of the signal-to-noise ratio is perhaps the following : under the same conditions as above a slice scan is placed on a short piece of a typical track. The track center coordinates are plotted as a histogram. From this histogram the r.m.s. scatter is calculated. Such a histogram is shown in fig. 17. The calculation yields $\sigma = 1.7\ \mu m$. Obviously this value will increase with decreasing contrast of the track images.

These values might be compared with the r.m.s. scatter which is found on a perfect black line on transparent background. In this case a typical value is $0.3 \div 0.4\ \mu m$.

From these results it can be expected that the inherent scatter of the ERASME measuring procedure is smaller than the scatter due to "film noise" and the scatter on the distribution of the bubble images on the photos.

REFERENCES

1. Video processing unit and Track Detection.
H. Anders and L. Sohet. DD 72-21. CERN/D.Ph.II/INST. 72-4.

2. J.A. Rosenthal and M. Fiehrer.
Automatic Gain Control for Photomultiplier Tubes. The Review of Scientific Instruments, Vol. 35, no. 11, Nov. 1964 p.1560-1563.

3. K. Wattenbach, JINR, Dubna, private communication.

4. G. Harigel, measurements on BEBC film, Sept. 1973, private communication.

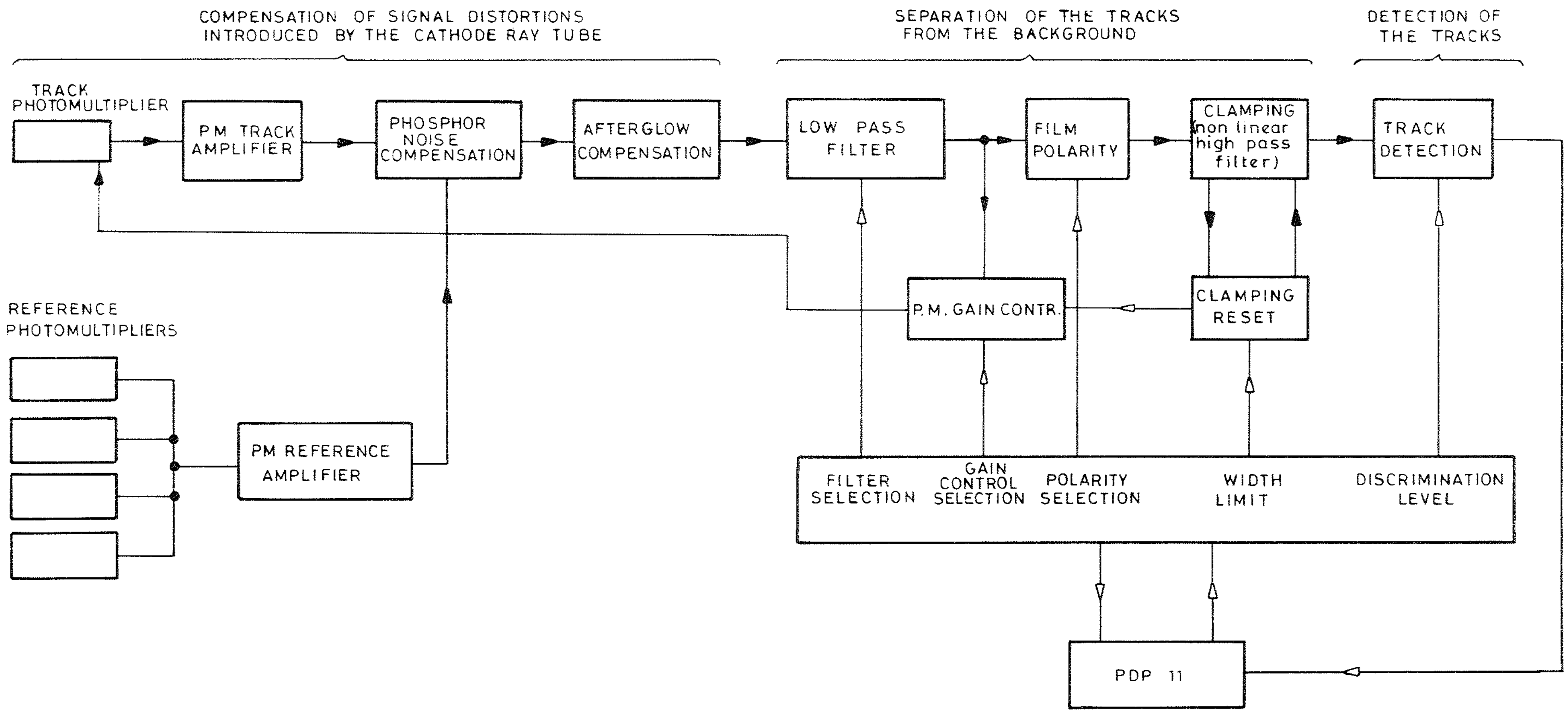


Fig. 1 – Block diagram video processing and track detection

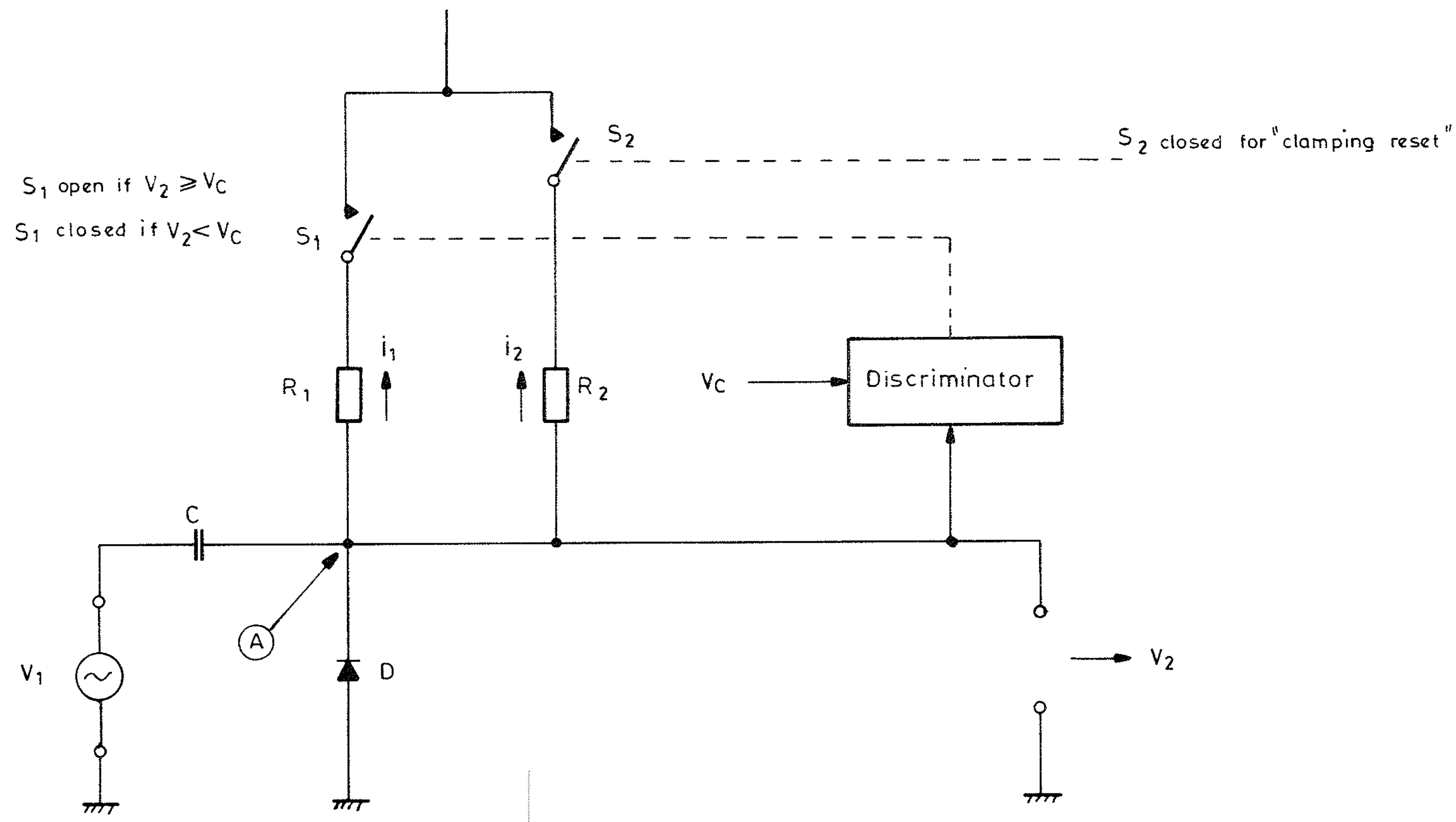
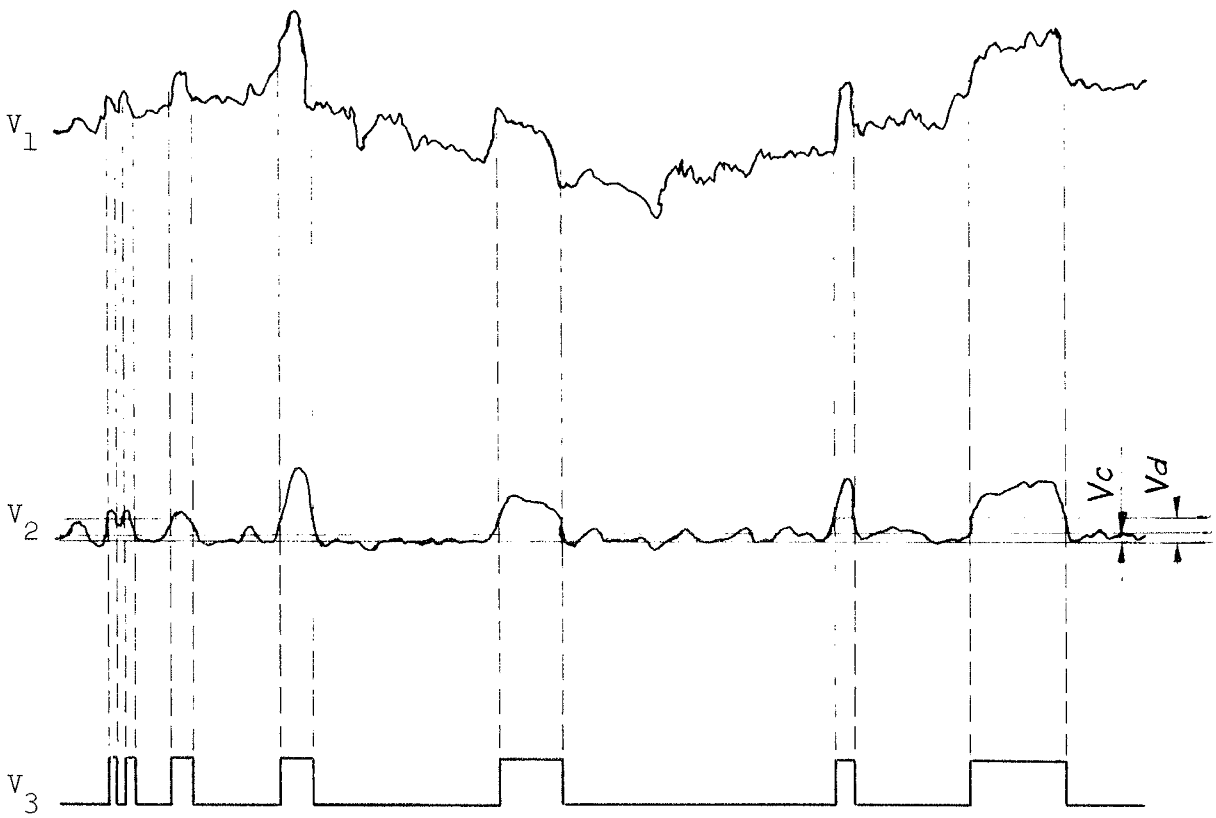


Fig. 2 — Simplified circuit diagram of the clamping stage



V_1 = track photomultiplier signal

V_2 = signal after filtering and clamping

V_c = threshold of the clamping stage

V_d = threshold of the track detector

V_3 = track pulses sent to digitizing logic

Fig. 3: Principle of the signal processing and track detection

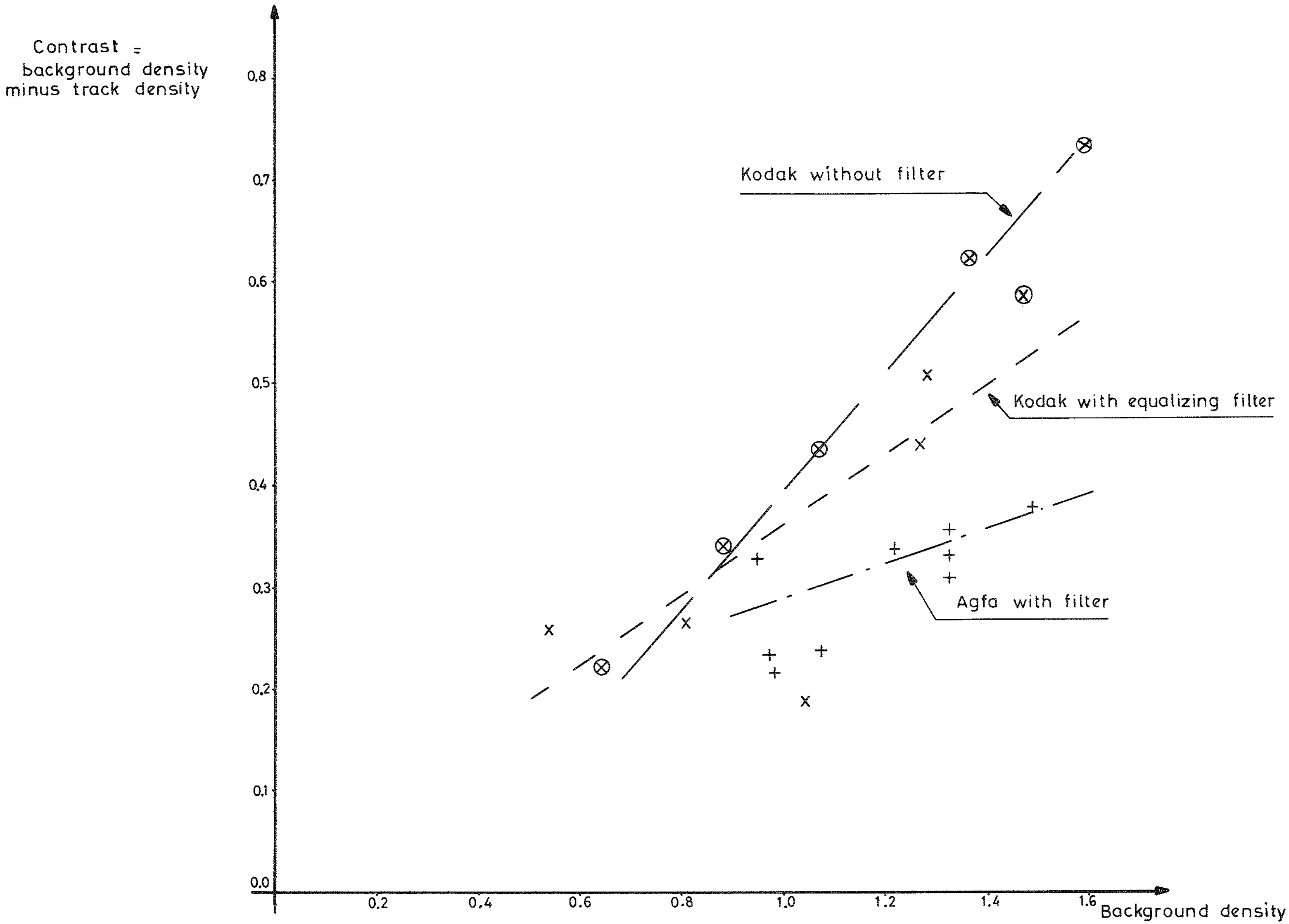


Fig. 4 — Track contrast as a function of background density

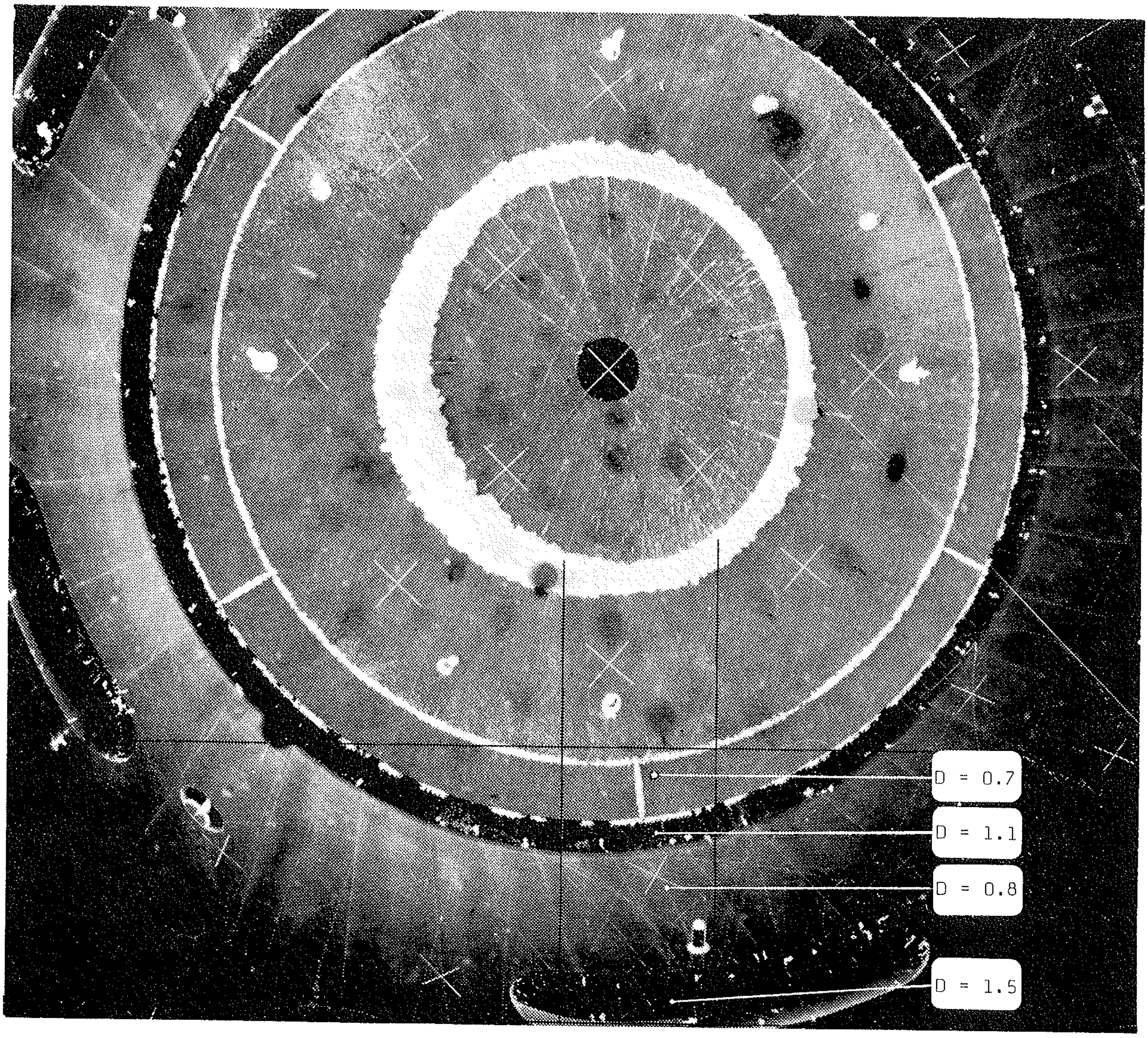


Fig. 5a. BEBC original (July 73 run)
The figure indicates the background density.

Note: The quality of the pictures improved considerably on the run of November 74.

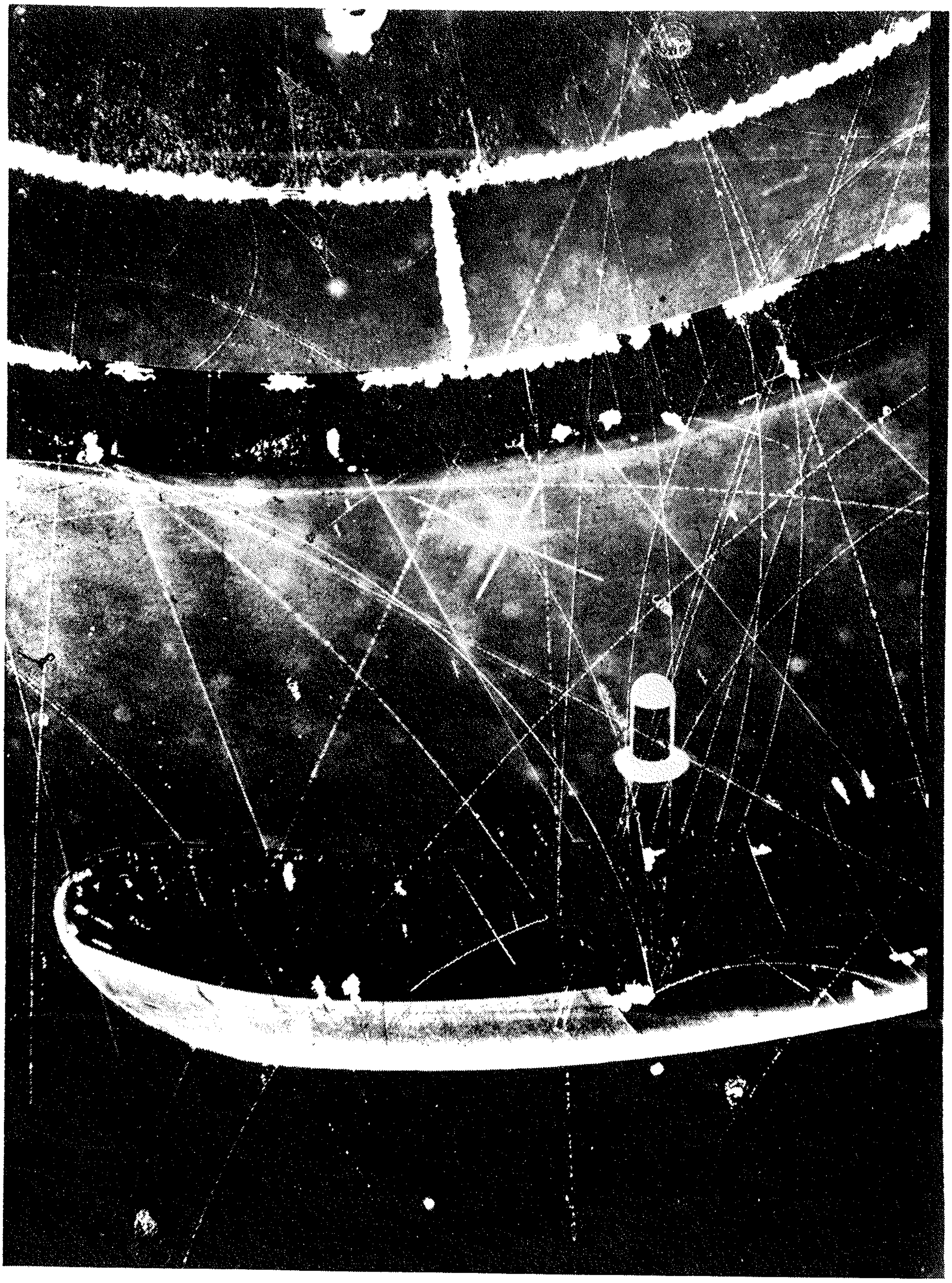


Fig. 5b. Enlargement of the original for
the area shown in Fig. 7.

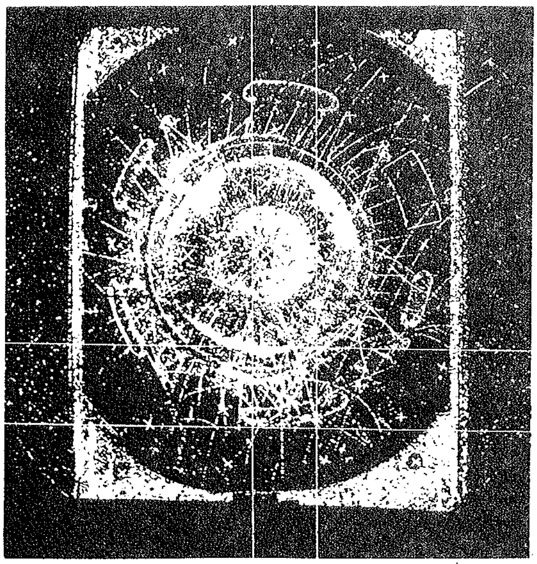


fig. 6. Reconstruction of the whole BEBC photo. The area of fig. 7 is marked

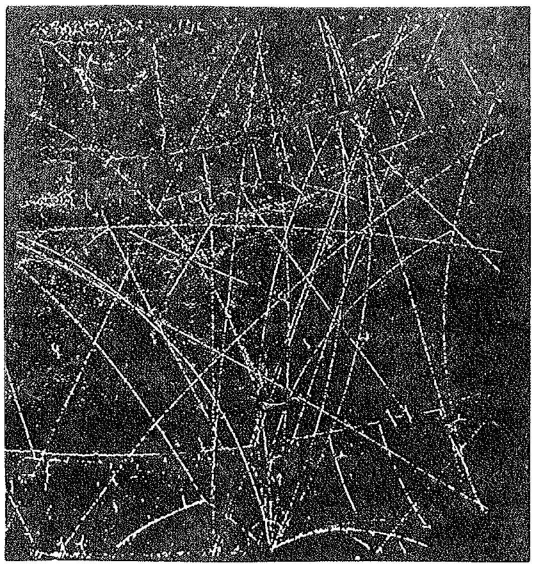


fig. 7. Enlarged area marked on figs. 5 and 6

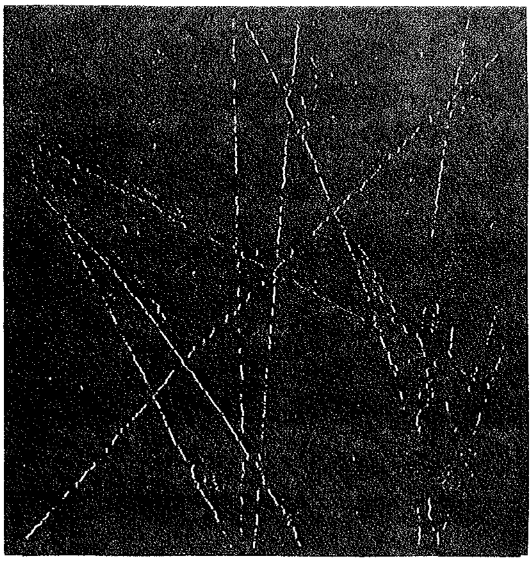


fig. 8. Enlarged scan of the centre of fig. 7
Horizontal scan.
Track centre displayed only.

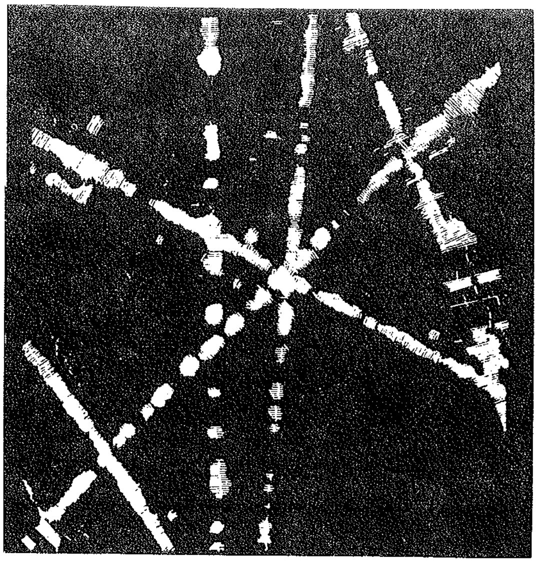


fig. 9. Same area as fig. 8 but with scans perpendicular to the tracks (track following mode).
Track centres and width are displayed. line distance 6μm

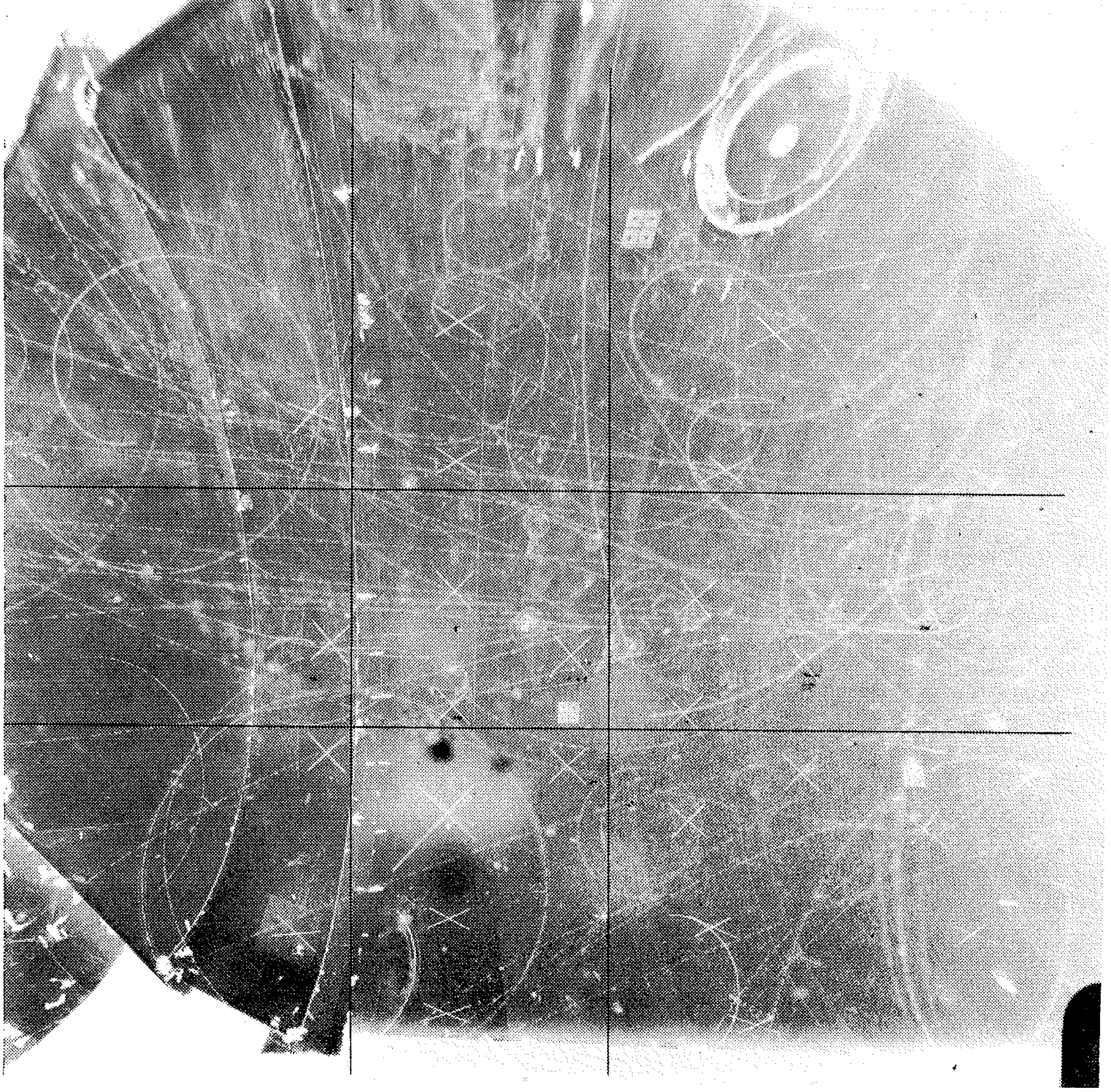


Fig. 10. MIRABELLE original
(Film 39 p 70 GeV/c, oct.72)

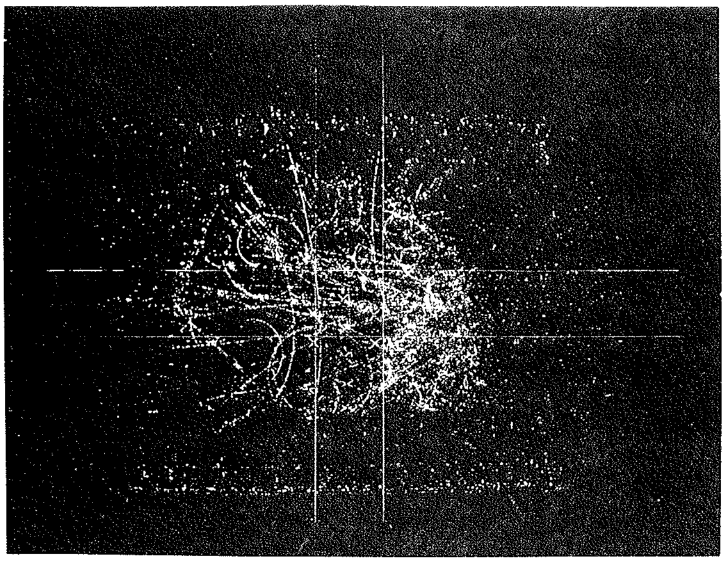


fig. 11. Reconstruction of the whole picture.
The area of fig. 12 is marked.

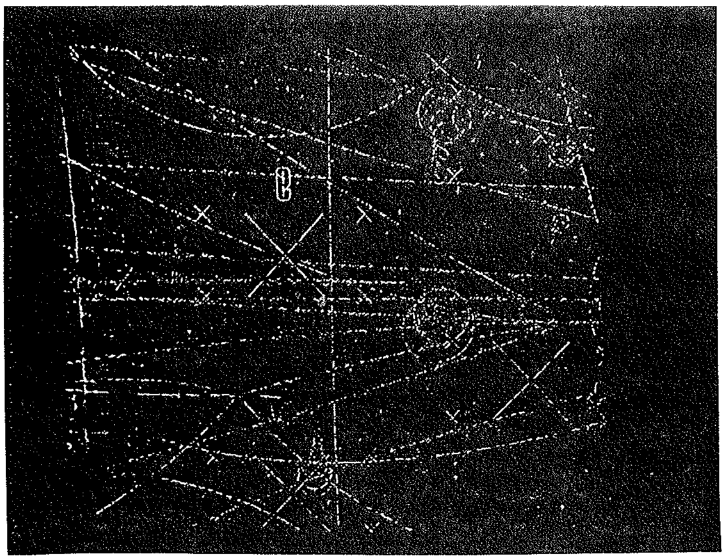


fig. 12. Enlarged area marked on figs. 10 and 11

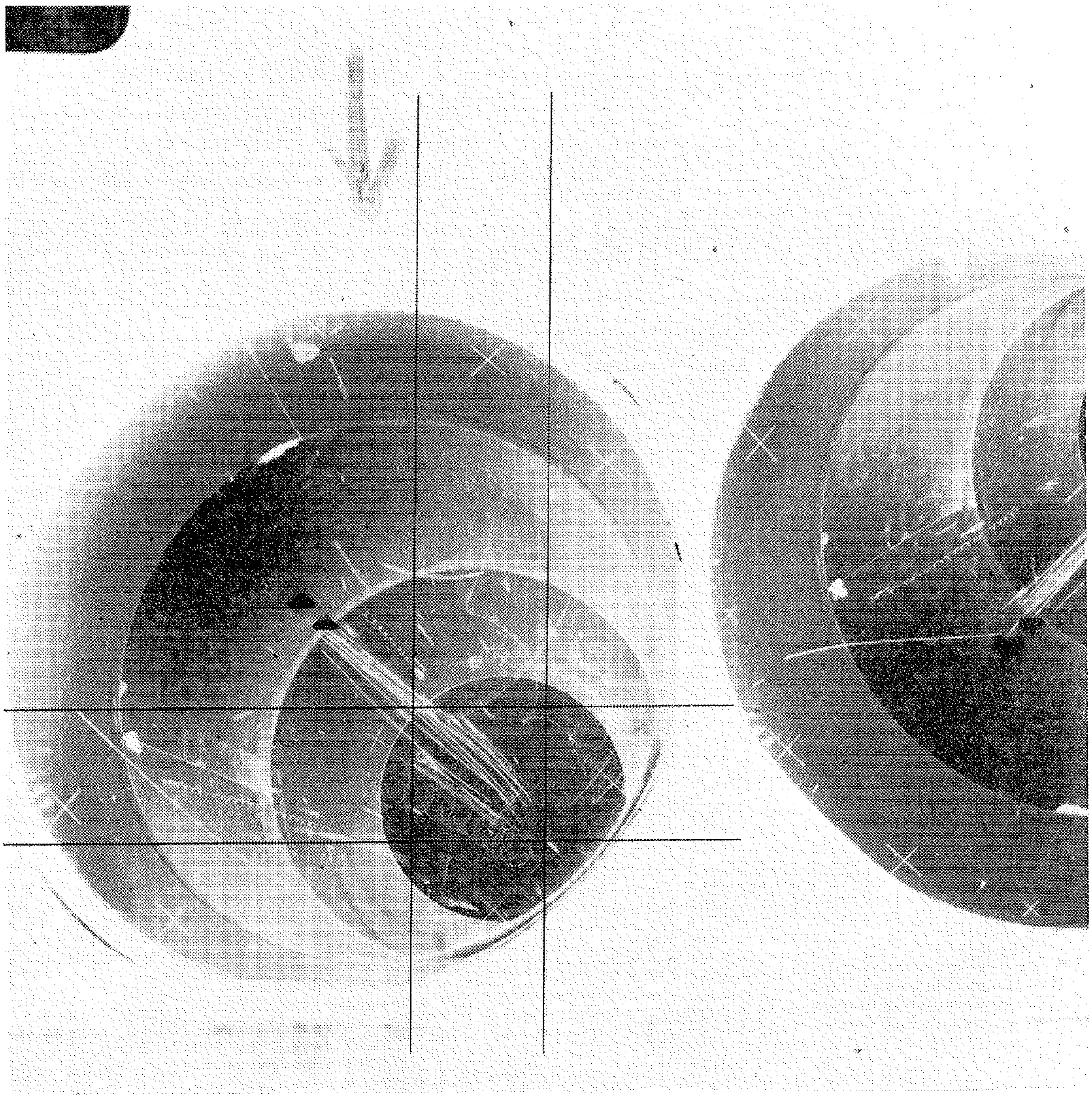


Fig. 13. HYBUC original

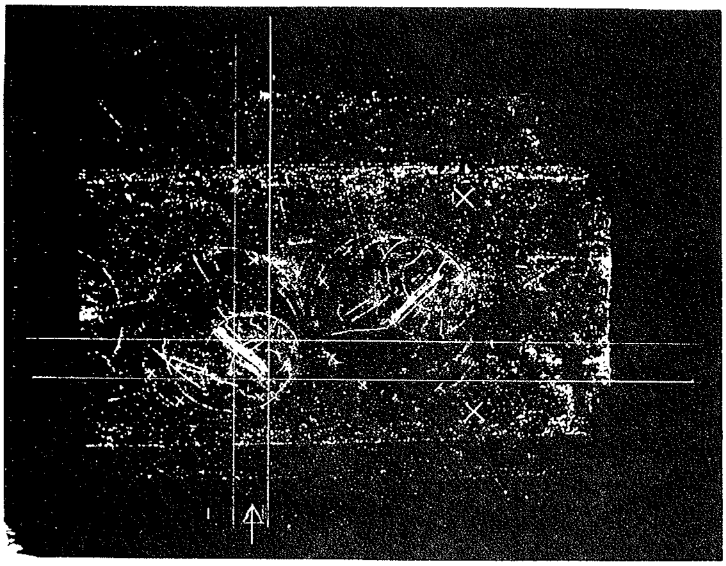


fig. 14. Reconstruction of the whole picture
Several views are covered by the scan.
The area of fig. 15 is marked.

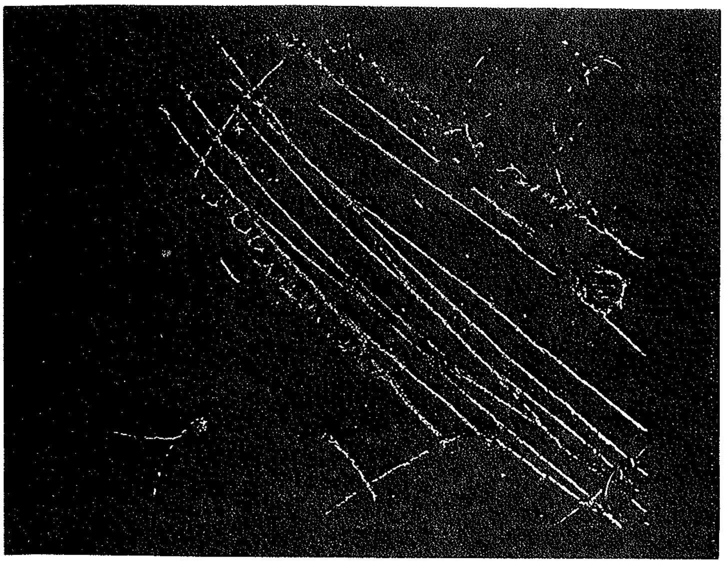
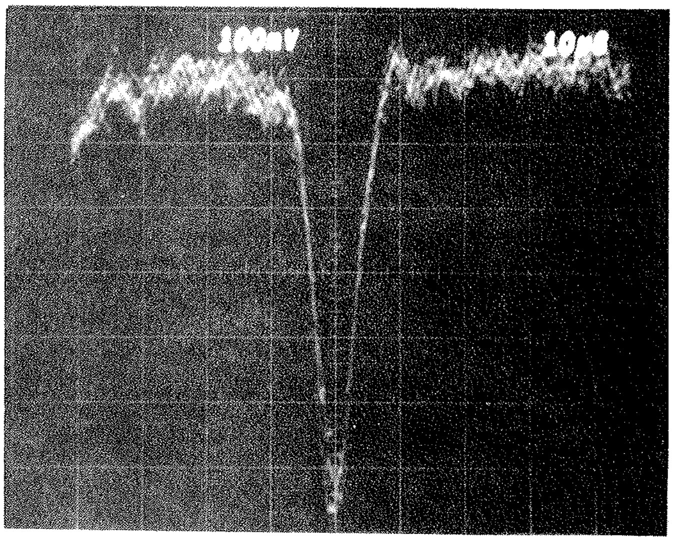


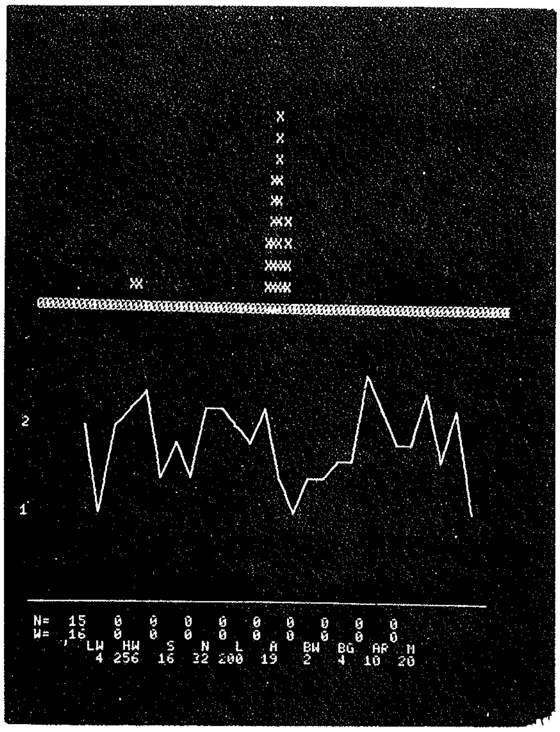
fig. 15. Enlarged area marked on figs. 13 and 14



D: 1.5

ΔD=0.5

fig. 16. Signal to noise ratio.
Track pulses of 32 lines scan one track superimposed.



A. Histogram of the track centres found during one slice scan. Each cross represents the position of one "hit" relative to the length of the scan line. Bin width 2 lc $\underset{\sim}{\sim}$ 3µm on film.

B. Plot of the track width of the "hits". The width varies between 10 and 20 lc $\underset{\sim}{\sim}$ 15 to 30µm.

C. Parameters of the slice scan.

fig. 17. Signal to noise ratio
histogram of the track centres