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## Proceedings

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# AUTOMATIC PROCESSING OF SPARK CHAMBER PICTURES AT DESY

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## 1. INTRODUCTION

In early 1964 we started to plan and construct a flying spot digitizer for the measurement of spark chamber pictures produced in experiments at DESY. At this time the experiment

$$\gamma + p \rightarrow p + \rho^{o}$$

was being prepared (1,2). We chose the specifications for the device according to the characteristics of these pictures although we could not hope to have finished the construction and the programs in time. Thus no effort was made to produce pictures perfectly suited to automatic measurement.

## 2. THE EXPERIMENT

Fig. 1 shows a picture of the $\gamma \rightarrow \rho^{o}$-experiment. A beam of tagged $\gamma$-rays hits a $H_2$ (C, Al)-Target. Two spark chambers define the production angle of the secondary particles. Their momentum is measured by a homogeneous magnet followed by two more spark chambers. A threshold Čerenkov-counter discriminates between pions and particles of higher mass.

Electrons are detected by two thick plate shower chambers.

Fig. 2 shows a typical picture to be processed. It contains the side and top views of the six chambers each with two rows of fiducial marks. In two gaps the side view tracks are optically displaced by a prism. This displacement is a function of the track position in the main view. It enables us to correlate main and side view tracks. The indicator lamps show the picture number, film number, Čerenkov-counter information and γ-energy. The double line by the side of the spark chamber images marks the area from which data have to be taken. The function of the inclined line will be described later. The demagnification ratio is 65 : 1.

## 3. THE DIGITIZER

Since the chambers are parallel and the accuracy parallel to the chambers has to be better than in the perpendicular direction, the use of a raster scan seemed convenient to us.

Due to the use of reversal film the pictures are fairly clean and almost all the information on them is useful. We therefore decided not to use a computer on-line, because neither the possibility of guiding the scan nor the large memory brings an advantage. Besides that, we reduced the area on the film from which data have to be taken by the previously mentioned special marks so that a 1 K memory is sufficient.

Fig. 3 shows a block diagram of the device. A raster scan of 512 lines with 14 ms sweep duration is produced on a Ferranti 5/29 AM cathode ray tube. It is projected by one of two objectives onto the picture and by the other onto a 20 μm picket fence grating, the lines being perpendicular to the grating. The light travelling through the transparent parts of the picture and the grating is sensed by two photomultipliers. Their output signals are fed to the digitizing unit which essentially contains a 12 bit binary counter for the grating signals, the frequency of which is multiplied by four. When



the double line is traversed by the scan, the counter is reset. Its content is therefore a measure of the distance of the light spot from the double line and is independent of the spot velocity. If a fiducial mark or a spark is found, counts at half-frequency are fed into the counter during the traversal of the spark. At the end of the spark, the content of the counter, which represents the coordinate of the spark centre, is transferred to the core memory. The lost counts are stored in a supplementary counter and are then added back to the main counter. At the end of a picture the data are written on magnetic tape.

The data appear on the magnetic tape as a string of words which have to be interpreted (see Fig. 4). Numbers less than 100 belong to the inclined line in front of the spark chambers. They represent the z-coordinates (perpendicular to the scan direction). The following numbers represent y- or x-coordinates. They are distinguished by their different ranges. A display unit permits us to display the digitized picture (read from the magnetic tape) on the screen of a storage oscilloscope.

Since there exists a fixed relation between the picture and the grating, the accuracy in the horizontal direction is independent of the velocity of the light spot. If the double line on the picture is parallel to the grating, vertical oscillations of the light spot do not affect the accuracy. At a typical inclination angle of $3^{\circ}$, errors are introduced which are in 90% of all cases less than 2 least counts. Fig. 5 shows the distribution of the measured coordinates of a fiducial mark for 100 pictures.

The accuracy in the vertical direction is given by the amplitude of the vertical oscillations of the light spot together with the jitter of the coordinates of the inclined line. Fig. 6 shows the distribution of z-coordinates in one chamber for 100 pictures.

The resolution for adjacent sparks is limited by the memory cycle time which corresponds to six least counts or 60 µm. An example is shown in Fig. 7.

Table 1 summarises the hardware specifications.

## 4. DATA PROCESSING

### 4.1 Fixed data

The data on the magnetic tape do not contain all the information necessary for a proper track reconstruction. Since the inclination of the chambers with respect to the scan direction may vary with different camera positions or adjustments of the film transport system of the digitizer, the z-coordinates are not exactly defined. The necessary data are obtained in the following way: a computer program plots the number of digitizations versus the z-coordinate for different chambers and different parts of them (as in Fig. 6). From these plots we take the relative gap positions with respect to the measured z-coordinates. These data are fed to the computer via data cards. This human intervention is not necessary, if the picture contains also inclined lines at the end of each chamber. Unfortunately, there was no space left in the experimental setup described here.

The above mentioned program also accumulates the fiducial coordinates for samples of 100 pictures and computes from the mean values the coefficients for correction polynomials which have to be applied to the x- and y-coordinates. Second order and fourth order polynomials are used for side and main view respectively. This procedure gives a very accurate correction for distortions introduced by the optics both of the setup and the digitizer.



### 4.2 Pattern recognition

#### 4.2.1 Labelling the digitizations

At the beginning of the pattern recognition program each digitization gets a label which is found by comparing its value and position in the data array to the known constants. This label contains the information specifying the kind of digitization (spark, fiducial mark, etc.), the chamber number and the gap number. So in the further processing the different groups of data may be treated separately according to their label.

#### 4.2.2 Formation of sparks

Since the spread of the digitizations around the spark centre is less than the resolution (see Fig. 7), the bunches of digitizations are well separated and can easily be grouped into sparks.

#### 4.2.3 Construction of track segments

We have two different ways of finding the track segments in the chambers. These have in common that one picks out an appropriate pair of gaps and forms hypothetical tracks from all possible combinations of sparks in these gaps. The hypothetical tracks which contain the greatest number of sparks are accepted as tracks. In one version of our program one starts with the gaps which contain a minimum number of sparks and which are the furthest apart from each other[(3)]. This method is based on the fact that it is very unlikely that a gap should contain no track spark, and yet does contain a spurious spark. The other version starts just with the first and the last gap of a chamber. The results of both methods do not show appreciable differences.

Since on most pictures the tracks are sufficiently separated and spurious sparks are rare, the hypothetical tracks with the highest number of sparks are in fact real tracks. If the tracks are close together, or even crossing, criteria have to be applied to identify the most likely tracks. These criteria are roughly the following: the track with most sparks on it has to be preferred. In one gap only one spark can contribute to a track. No spark can belong to two tracks. If it is doubtful with what track a spark should go, a least squares fit decides this question. Finally the slope of the track should be compatible with the experimental conditions.

In principle there is no difference between side and top view tracks. In the side view, however, two sparks of each chamber are displaced by the prism and therefore cannot be used for the segment construction. Besides that, the probability of overlapping tracks is higher than in the top view. Therefore track reconstruction becomes more difficult. But on the other hand one can use the sparks of all chambers simultaneously, because no deflection takes place in the magnet.

#### 4.2.4 Combining track segments to "links"

Once the track segments in adjacent chambers are found they have to be combined to form "links". A least squares fit for every combination of track segments for two chambers is performed. The combination with the smallest deviation of the sparks from the fit is accepted as a link.

#### 4.2.5 Reconstruction of the tracks in the laboratory coordinate system

For this purpose it is necessary to find the correlation between the two projections of side view and top view tracks. In most cases the correct correlations are found by using the sparks displaced by the prism. If this method does not work because of the lack of sparks, the track patterns of the two views are compared. If the tracks have been found correctly, a correlation is practically always possible. When the correlations are found, a transformation which corrects for the parallax is made. A final least squares fit establishes the



final track coordinates. From then on, the data are processed in the same way as the measuring table data. The program used with the data from the scanner also computes approximate values for the physical results. Figs. 8 and 9 give an impression of the measured momentum of a particle in 100 measurements. Fig. 9 shows a similar distribution for the mass of the two-pion system.

The overall time to compute an event is about 2.7 s with about 1.8 s for the pattern recognition part. The program needs 22 K words of memory in an IBM 7044 computer.

## 5. RESULTS

In the experiment described 13000 pictures have been taken. 7800 of these were usable for physics. These pictures were measured with the following result:

| | | | |
|---|---|---|---|
| 7800 | pictures | (100 %) | processed |
| 5900 | pictures | ( 76 %) | measurement successful |
| 1900 | pictures | ( 24 %) | measurement failed |

The failures have the following causes:

| | |
|---|---|
| 12 % | construction of two tracks in the side view impossible |
| 6 % | ambiguous correlation between side view and top view tracks |
| 5 % | improper film development, stray light etc. |
| 1 % | identification of two tracks in the top view impossible |

A new spark chamber experiment is now in preparation which will involve several hundred thousand pictures. It is completely designed for automatic data processing. We think that with the experience now gained we can improve the quality of the pictures and so increase the total efficiency to more than 90 %.

References

1. H. Blechschmidt et al. Proceedings of the International Symposium on Electron and Photon Interactions at High Energies, Hamburg, 1965.

2. H. Blechschmidt et al. (to be published).

3. P.M. Blackall et al. CERN 63 - 34, 141, 1963.

TABLE I

| | |
|---|---|
| Accuracy | (for a frame of 24 x 36 mm) |
| horizontal | ± 10 μm (90 %) |
| | ± 20 μm (10 %) |
| vertical | ± 36 μm rms. |
| Resolution for adjacent sparks | 60 μm |
| Measuring time | 8 s/frame |
| Flying spot generator | |
| diameter of the light spot | 30 μm (= 20 μm on the picture) |
| dimension of the raster | 36 x 54 mm (=24 x 36 on the picture) |
| sweep time | 10 ms |
| recovery | 4 ms |
| number of lines | 512 |
| Digitization | |
| least counts/line | 3600 |
| storage capacity | 1024, 12 bit words |
| tape length/picture | 8.4 cm |
| Film transport system | |
| accuracy | ± 0.5 mm |
| transport time | 1.0 s |

Figure captions

Fig. 1 Experimental setup of the $\gamma$-$\rho^{o}$-Experiment

Fig. 2 Spark chamber picture of the $\gamma$-$\rho^{o}$-Experiment

Fig. 3 Block diagram of the Flying Spot Digitizer

Fig. 4 Interpretation of the measured values

Fig. 5 Distribution of the measured x-coordinates of a fiducial mark for 100 pictures

Fig. 6 Distribution of the z-coordinates in one chamber for 100 pictures

Fig. 7 Crossing tracks (a) on the picture, (b) reproduced by the computer

Fig. 8 Distribution of particle momentum for 100 measurements of the same picture

Fig. 9 Distribution of the dipion mass for 100 measurements of the same picture.

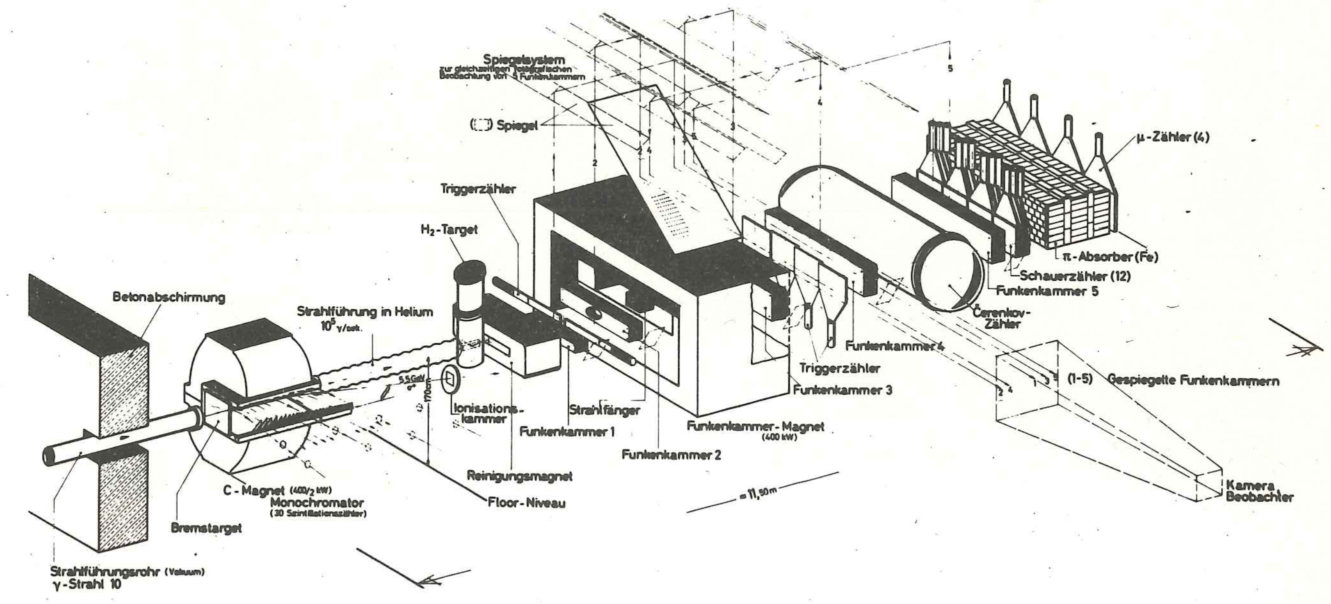

Spiegelsystem
zur gleichzeitigen fotografischen Beobachtung von 5 Funkenkammern
Spiegel
Triggerzähler
$H_2$-Target
Betonabschirmung
Strahlführung in Helium
$10^5$ γ/sek.
5,5 GeV
170cm
Ionisations-kammer
Strahlfänger
Funkenkammer 1
Funkenkammer 2
Reinigungsmagnet
Floor-Niveau
C-Magnet (400/2 kW)
Monochromator
(30 Szintillationszähler)
Bremstarget
Strahlführungsrohr (Vakuum)
γ-Strahl 10
Funkenkammer-Magnet
(400 kW)
Funkenkammer 3
Triggerzähler
Funkenkammer 4
Čerenkov-Zähler
Funkenkammer 5
Schauerzähler (12)
π-Absorber (Fe)
μ-Zähler (4)
(1-5) Gespiegelte Funkenkammern
Kamera
Beobachter
≈ 11,50 m

FIG. 1

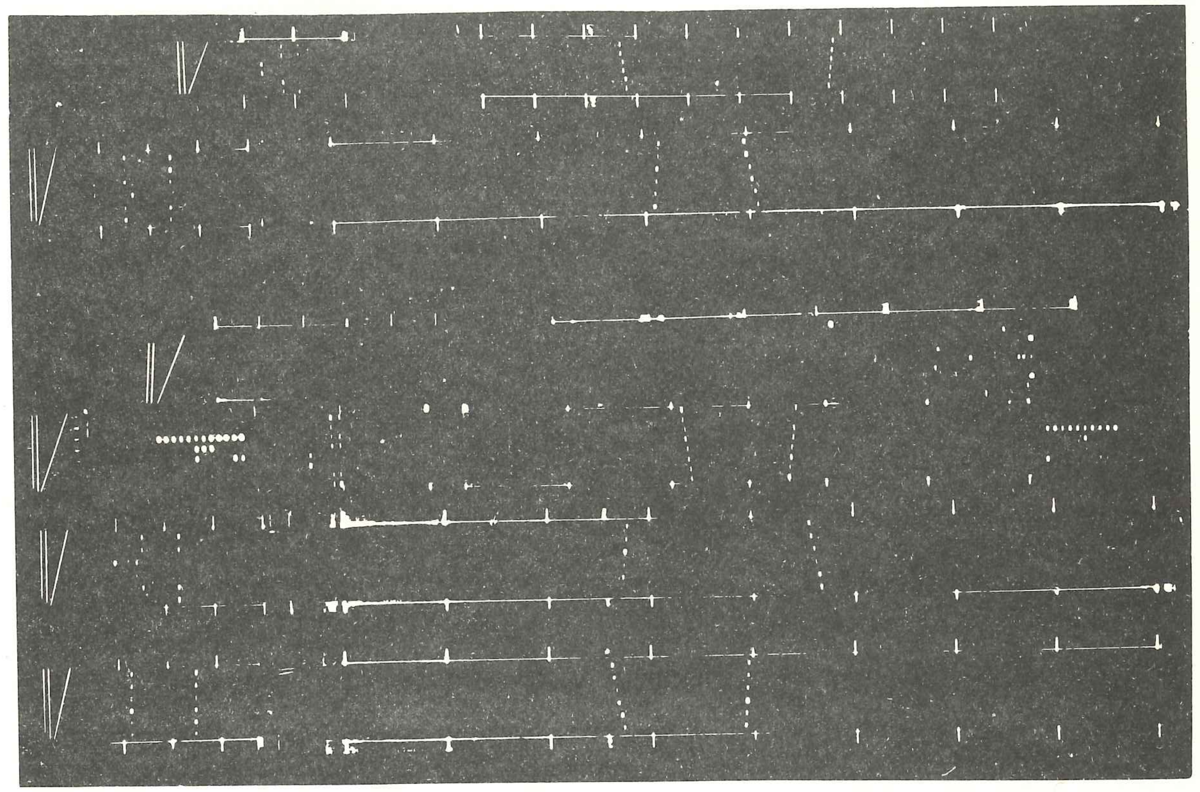


FIG. 2

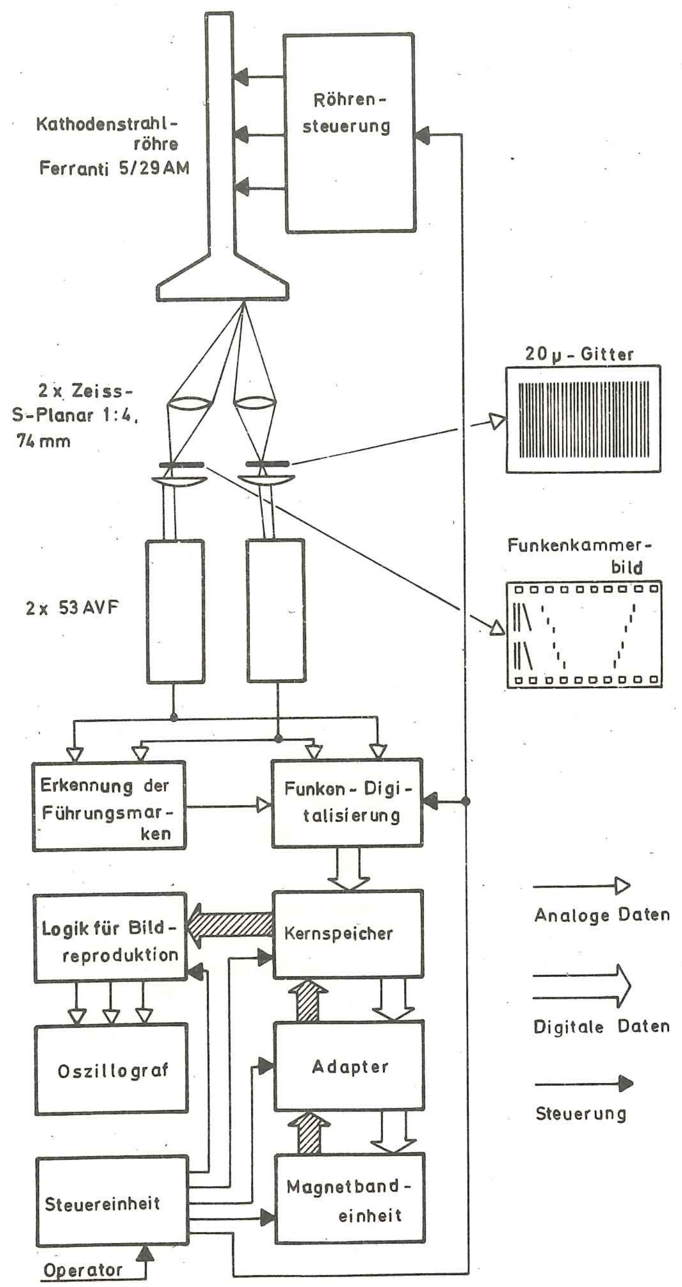

Röhren-
steuerung
Kathodenstrahl-
röhre
Ferranti 5/29 AM
2 x Zeiss-
S-Planar 1:4,
74 mm
20 μ - Gitter
Funkenkammer-
bild
2 x 53 AVF
Erkennung der
Führungsmar-
ken
Funken - Digi-
talisierung
Logik für Bild-
reproduktion
Kernspeicher
Oszillograf
Adapter
Steuereinheit
Magnetband-
einheit
Operator
Analoge Daten
Digitale Daten
Steuerung

FIG. 3

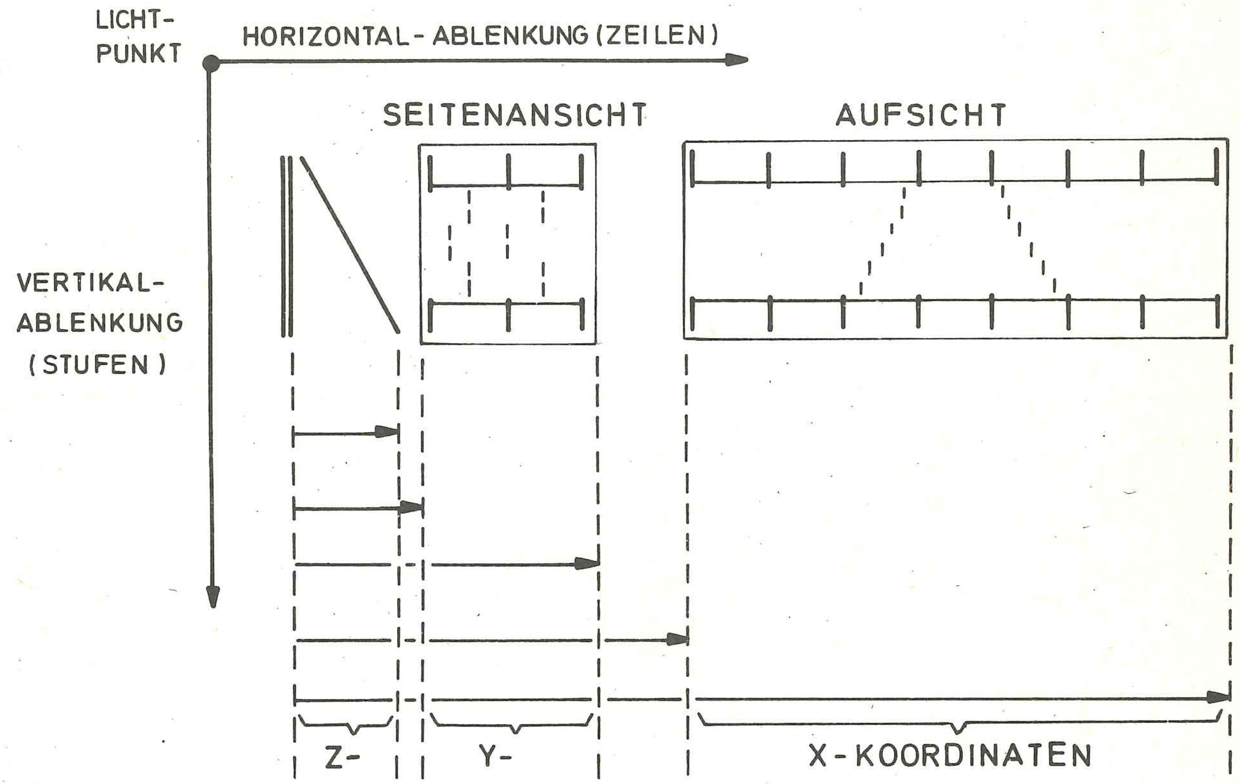

LICHT-
PUNKT
HORIZONTAL - ABLENKUNG (ZEILEN)
SEITENANSICHT
AUFSICHT
VERTIKAL-
ABLENKUNG
(STUFEN)
Z-
Y-
X-KOORDINATEN

*FIG. 4*

TESTPUNKT NR. 9

EICHMARKEN AUF KAMMER 2    BAND E8/4    FILM 32
DAS MAXIMUM IST AUF 50 NORMIERT
ANZAHL DER ABTASTUNGEN=100

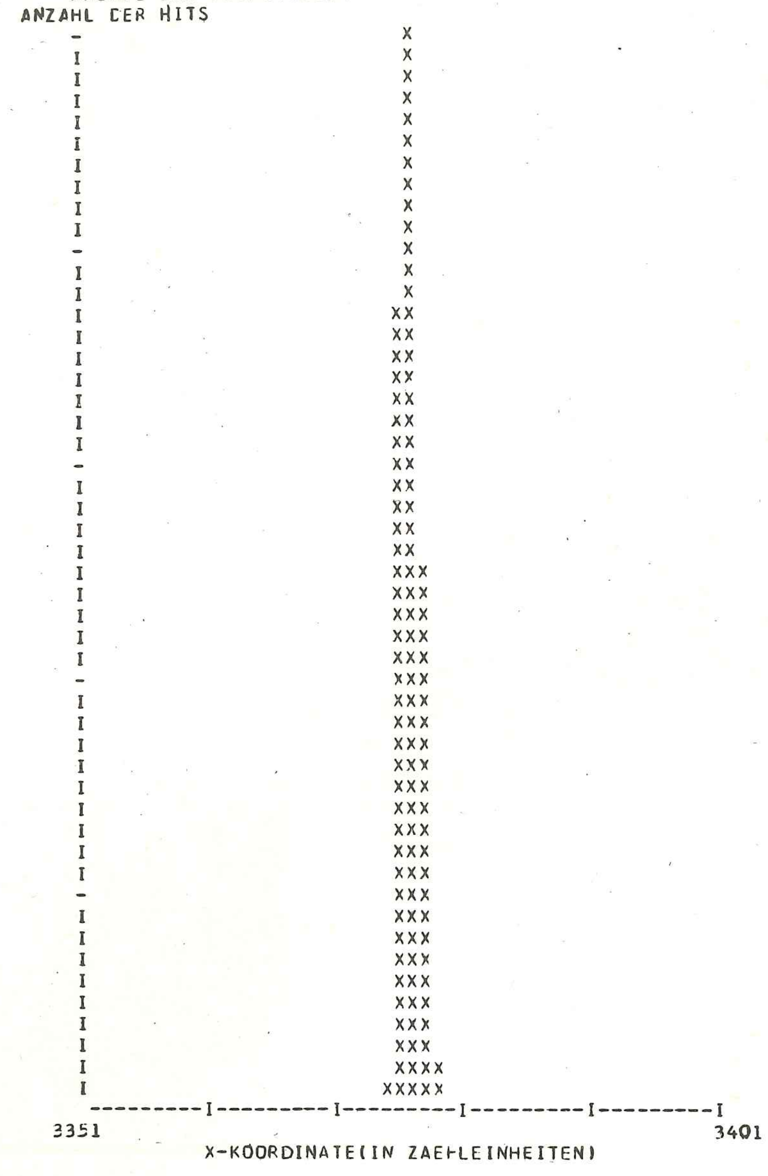



FIG. 5

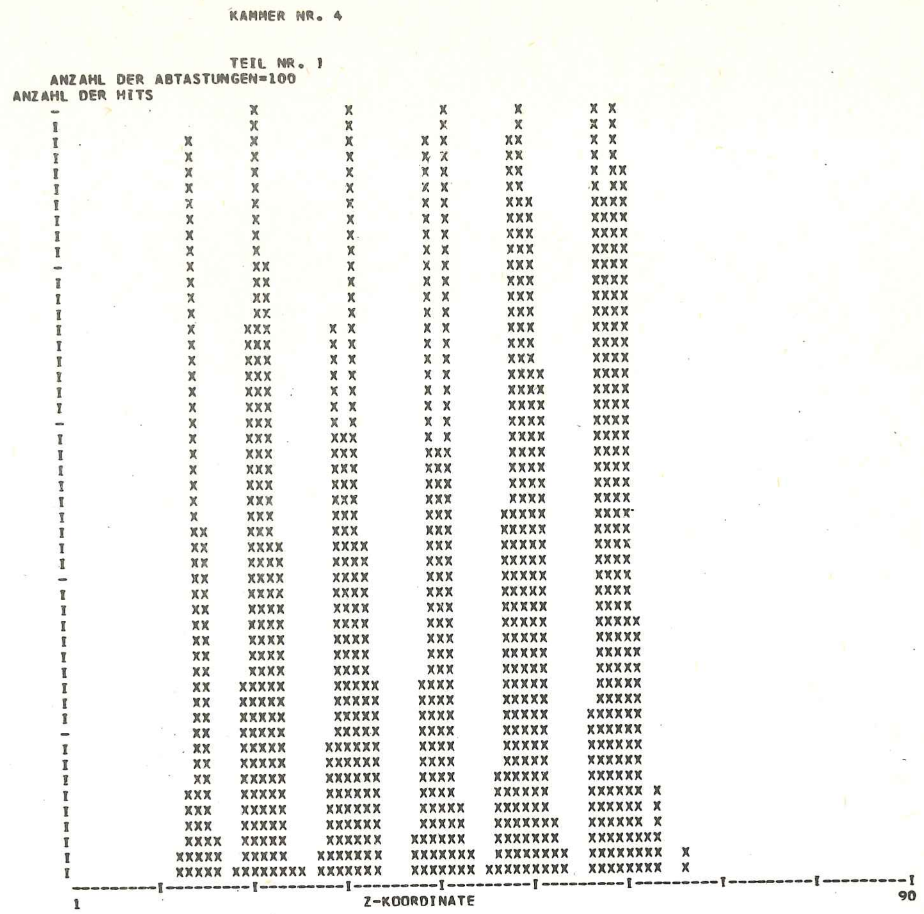

KAMMER NR. 4
TEIL NR. 1
ANZAHL DER ABTASTUNGEN=100
ANZAHL DER HITS
Z-KOORDINATE
1
90

FIG. 6

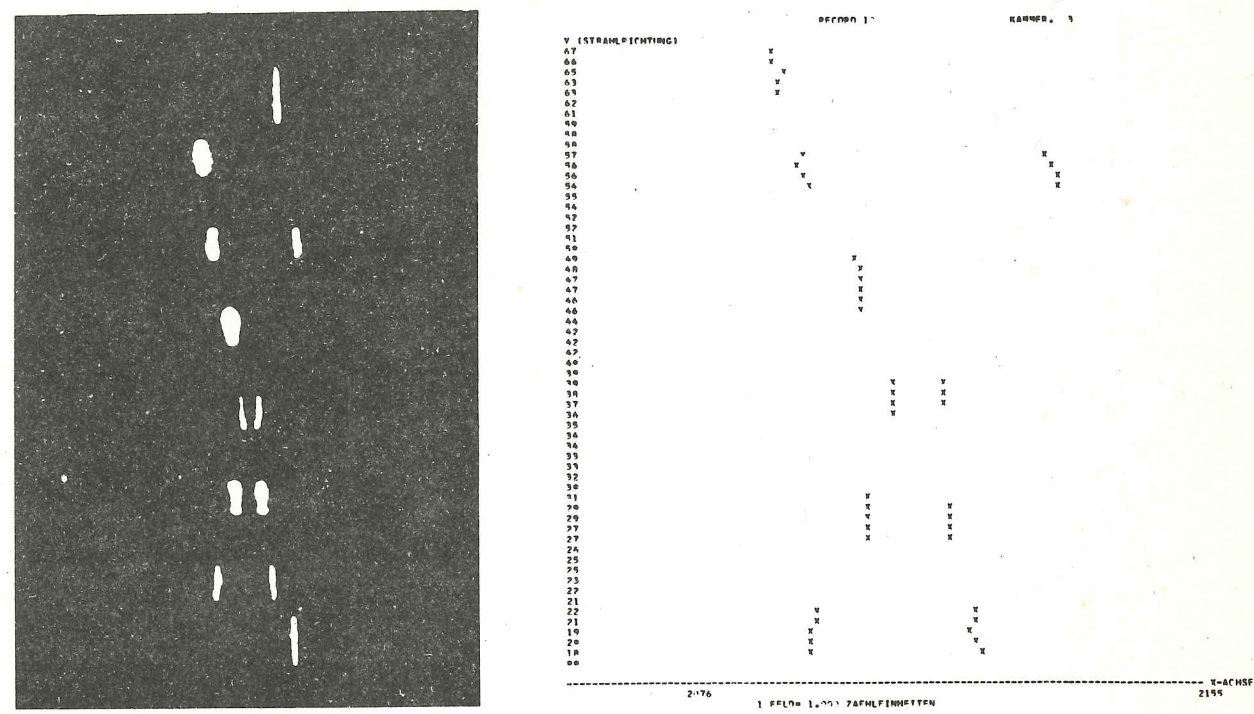
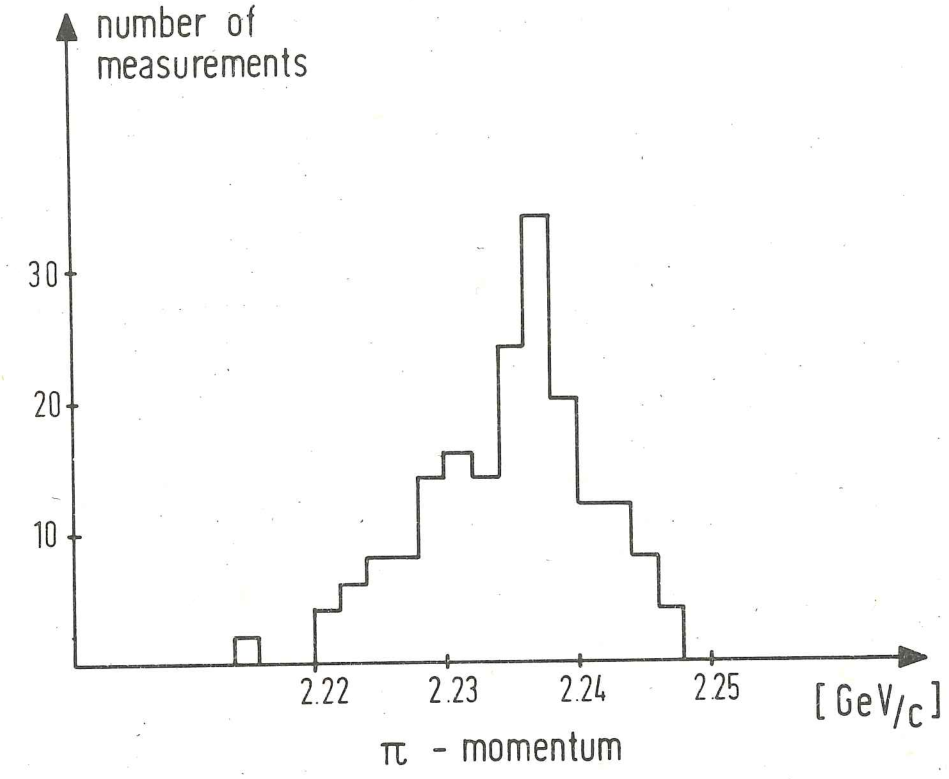


FIG. 7



number of
measurements
30
20
10
2.22
2.23
2.24
2.25
[GeV/c]
π - momentum


*FIG. 8*

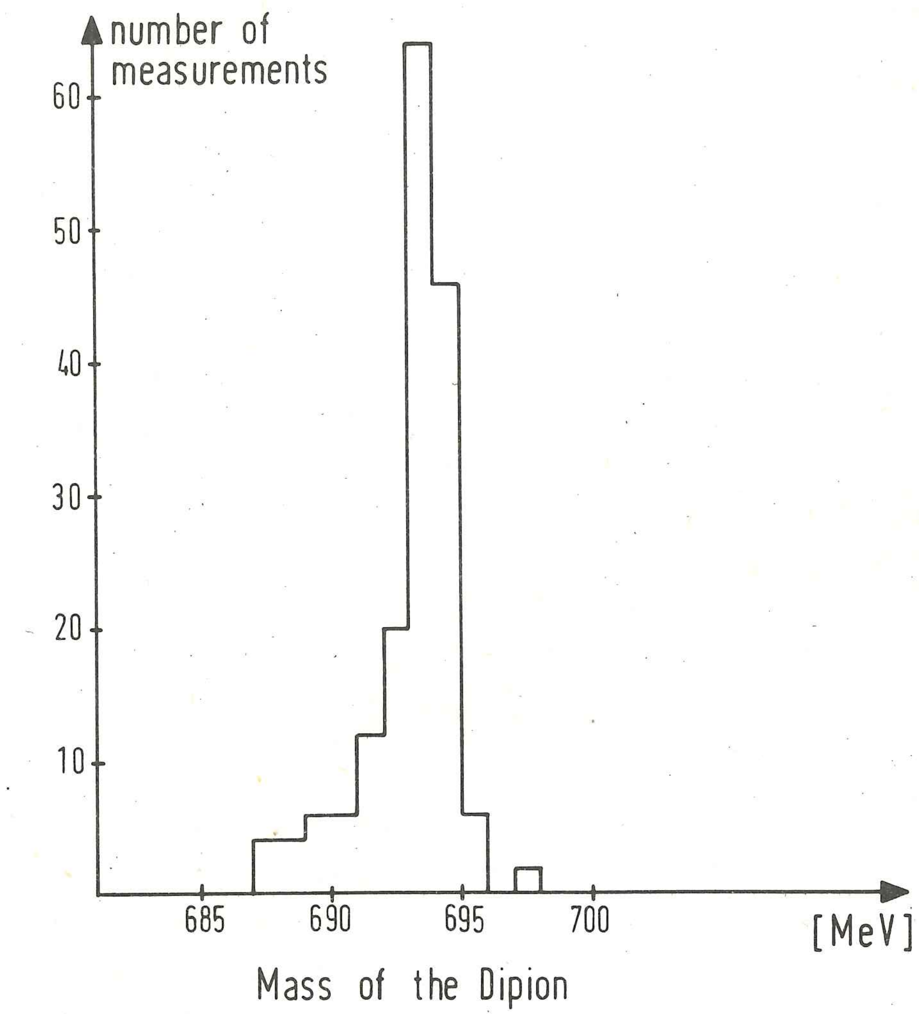

number of measurements
60
50
40
30
20
10
685
690
695
700
[MeV]
Mass of the Dipion

*FIG. 9*